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FUTURE MEETINGS OF THE BRITISH ASSOCIATION

THE British Association has found it impossible to arrange this year an annual meeting on the lines of the pre-war meetings in provincial cities. A one-day meeting will therefore be held, on Saturday, July 20, in London. The British Medical Association has generously granted the use of its hall for this occasion. Statutory meetings of the Council and the General Committee will be held in the morning; and at a general meeting in the afternoon the Presidential Address will be delivered by Sir Richard Gregory, Bt., F.R.S. There will be no sectional meetings.

Opportunity will be taken to receive delegates attending the Empire Scientific Conference organised by the Royal Society, and the Commonwealth Scientific Official Conference, at a luncheon on July 20 and at the subsequent meeting, and also, it is hoped, at a Sunday afternoon reception at Down House, the home of Charles Darwin, which the Association maintains as his memorial. The Association will by this means find occasion to express its gratitude to the Dominions and to India, in which some of the most notable meetings in its history have been held. It is also hoped to receive some of the foreign delegates who are expected to be in England at that time.

A Conference on UNESCO and Universities will be held jointly by Section L (Education) and the Division for the Social and International Relations of Science on Monday, July 22, in London.

An autumn Conference on the Scientific Planning of London, with special reference to correlation of overground and underground transport with surface features, is under consideration by Section G (Engineering) and the Division for the Social and International Relations of Science.

Full particulars will be issued to members of the Association in due course.

It is intended to resume normal meetings in subsequent years, and an invitation has been accepted for the meeting in 1947 to be held in Dundee, where the meeting in 1939 was cut short by the imminence of war. An invitation from Brighton for 1948 has also been accepted.

SCIENTIFIC RESEARCH AND INDUSTRIAL PLANNING

TRANSACTIONS OF A CONFERENCE HELD BY THE DIVISION FOR THE SOCIAL AND INTERNATIONAL RELATIONS OF SCIENCE, DECEMBER 7–8, 1945

A CONFERENCE on Scientific Research and Industrial Planning was held, by kind permission, in the London School of Hygiene and Tropical Medicine, on Friday and Saturday, December 7 and 8, 1945. There were morning and afternoon sessions on each day.

FUNDAMENTAL RESEARCH IN RELATION TO THE COMMUNITY

FRIDAY, DECEMBER 7, 1945: MORNING SESSION

OPENING BY SIR RICHARD GREGORY, BT., F.R.S., PRESIDENT OF THE ASSOCIATION AND CHAIRMAN OF THE SESSION

MUCH has been said and written recently on the subject of scientific research and more on the social and moral attitudes towards it. Four different aspects of the subject will be presented in the separate sessions of this Conference; and it is hoped that consideration of them will assist in promoting new conceptions relating to the motive and purpose of the pursuit of natural knowledge and some of their contacts with modern life.

Though science is systematic and formulated knowledge in all fields of human understanding—natural, moral, social and political—yet, by general usage, scientific research now signifies the intensive study of natural structures, properties, processes and events, whether carried on as an intellectual pursuit or for industrial exploitation.

At this opening session of the Conference the term fundamental research may be said to signify investigations carried on with the single motive of acquiring new knowledge, the results of which are communicated freely to the whole world. Studies of this kind have to be planned whether undertaken by individuals or for team-work, but their purpose is the discovery of truth for its own sake rather than for its practical value.

The second session of the Conference will be concerned mainly with scientific research planned to meet modern needs of life and promote technological progress. Research of this kind does not, however, exclude close attention to what may be termed purely scientific problems and principles. Indeed, the methods are the same, and the threads of discovery are so closely enmeshed in the pattern of science that they cannot be easily separated.

The third and fourth sessions will be concerned with some of the repercussions between research and the community from the points of view of economics and the human factor, which can never be rightly expressed in terms of mechanical efficiency.

The title of the Conference and the general plan of the programme were decided upon by the Council of the Association before the application of atomic energy to the construction of bombs terrified the civilised world in August last. Since then, each of the themes of the four sessions of the Conference has been given concentrated public attention through the use of these lethal weapons.

The fundamental principles involved in the production of instruments of this kind were established by purely scientific research in the laboratories of the chief countries of the world, and were described and discussed at every stage of their development. The conversion of such principles and laboratory experiments into industrial installations demands researches planned with useful service as their purpose. This is the province of the inventor and engineer, who design machines and processes to supply social needs, whether in times of peace or of war. At every stage of industrial enterprises of this kind, discoveries are made as to the most efficient methods and materials to adopt for practical production. Descriptions of these technical advances are not, however, usually communicated to scientific societies, and are either kept secret or are included in specifications of patents.

Hundreds of such technical details had to be worked out in the release and control of atomic energy as a new and unlimited source

of natural power. There is no industrial or economic reason why these should be divulged, except that of the spirit of international altruism. What has now, however, been proved is that this energy can be harnessed and made available to the human race. Before that had been done on an engineering scale, no one could have predicted, with confidence, how to put the use of atomic energy into practice or what the immediate effects would be.

These questions have now been answered in a manner which removes all doubt as to the validity of the conclusions relating to the vast stores of nuclear energy in the atom and the possibility of making use of it. From a scientific point of view, this confirms the truth of mathematical propositions and laboratory results contributed by scientists of many lands towards the understanding of natural structures and forces. Their particular interest was, and is, in nuclear fission and the starting of a chain-reaction in atomic disintegration, and not in the use of the energy set free for the manufacture of shattering bombs.

From an industrial point of view, the immense cost of erecting the machinery necessary to carry out large-scale operations of this kind would not have been an economic possibility for many years to come. Costs, however, are not counted in times of totalitarian warfare, when the aim is to obtain supremacy by force, and all citizens are called upon to render service directly or indirectly to this end. Civilisation has not reached the stage at which what are believed to be the rights of peoples can be asserted or maintained except by force of arms. The violence of atomic energy when used to enforce such power, however, has sounded a note of alarm at the disastrous consequences to the whole civilised world unless the application of this energy to the manufacture of weapons is outlawed.

The joint statement made by the President of the United States, the Prime Minister of the United Kingdom and the Prime Minister of Canada, in the middle of last month, deals with this outlook and their attitude towards it. This is not an appropriate occasion or assembly at which to consider the safeguards or recommendations in the nine points of the Three-Power statement. It is, however, appropriate to mention that the subjects of the four sessions of the present Conference—fundamental research, planned research, economic aspects and the human factor—all come under consideration in the statement.

Freedom of thought and expression as an axiom of scientific inquiry is accepted in the words from clause 5 of the statement: 'We believe that the fruits of scientific research should be made available to all nations and that freedom of investigation and free interchange of ideas are essential to the progress of knowledge. In pursuance of this policy, the basic scientific information essential to the development of atomic energy for peaceful purposes has already been made available to the world.'

These principles express rights and responsibilities which have for long been followed in the fields of both pure and applied science. They are represented by the thousands of original communications published every year by scientific and technical societies and in specialised periodicals. This free trade in ideas and results of research does not, however, exist for details of processes discovered during the development of principles for industrial purposes. Specialised knowledge of this kind relating to atomic energy is now in the joint possession of the United States, Great Britain and Canada, and is of the nature of trade secrets. The second half of clause 5 in the statement of these three Powers expresses their views upon this subject as follows: 'It is our intention that all further information of this character that may become available from time to time may be similarly treated. We trust that other nations may adopt the same policy, thereby creating an atmosphere of reciprocal confidence in which political agreement and co-operation will flourish.'

The proposals referring to 'basic scientific information' do not introduce any new conditions into research work in pure or applied science or the exchange of ideas by the publication of results. The difficulty will be in deciding what additions to knowledge gained by scientific research are of basic or fundamental type and what might be withheld or patented because of their direct usefulness. As is well known, fundamental research undertaken with the single motive of extending the boundaries of knowledge has provided the seeds from which scientific industries have cultivated great plantations and gathered rich harvests of fruits. Planned or industrial research with profitable service as its object leads also to discoveries of basic scientific value, but whether these will eventually be usefully exploited or not can rarely be predicted.

All these considerations relate to Scientific Research and Industrial Planning as factors of national policy and progressive human welfare. They have been given particular significance in the whole civilised world by the invention of means to release and control atomic energy as a prime source of power. There can be little doubt that this source will be available eventually for industrial service and will thus increase the number of mechanical

slaves at the disposal of the human race. Meanwhile, if the world is to be protected from the further use of atomic energy in weapons of war and from the manufacture of all other major weapons adapted for mass destruction, it is urgently necessary for civilised peoples to understand this suicidal menace and institute effective safeguards against it.

That is the meaning and purpose of the Three-Power Statement, which presents a strong case for the constitution of a Commission under the United Nations to save others as well as themselves from such a catastrophe. Unless an agreement can be reached in the spirit of the statement, the day will surely come when, in the words of the day of judgment recorded in the Second Epistle of St. Peter, ' the heavens shall pass away with a great noise, and the elements shall be dissolved with fervent heat, and the earth and the works that are therein shall be burned up.'

Prof. Michael Polanyi, F.R.S.

The Social Message of Pure Science

I HAVE been asked to talk about fundamental science in its relation to the community. This relation was rarely discussed until about ten years ago, but since then, rather suddenly, it has become a major problem. What justification is there in scientific studies having no visible practical use? Until fairly recently it used to be assumed that such studies served their own purpose, namely the advancement of knowledge—the discovery of knowledge simply for the love of truth. Do we still fully accept that view? Do we still believe that it is proper for a scientist to spend public funds for the pursuit of studies such as, say, the proof of Fermat's theorem, or the counting of the number of electrons in the universe? Studies which, though perhaps not lacking in some very remote possibility of practical usefulness, are at any rate as unlikely to yield a material dividend as any human activity, within the realms of sanity, could possibly be. No, we do not generally accept today, as we did until the 1930's, that it is proper for science to pursue knowledge for its own sake, quite regardless of any advantage to the welfare of society. Never was there more talk about science —never less heard about the love of knowledge. We are faced here with a turn to a radically utilitarian attitude reflecting the general philosophical trend of our time.

The philosophical movement which has so effectively impaired the traditional standing of science has been attacking it from two different sides. One line of attack was directed against the claim of science to speak in its own right. This is the line of modern materialistic analysis which denies that the human intellect can operate independently on its own grounds and holds that the purpose of thought is at bottom always practical. Science in this view is merely an ideology, the contents of which are determined by social needs, and the progress of science is seen as depending on a series of successive dominant practical interests. Newton, for example, is then represented as discovering gravitation in response to rising navigational interests, and Maxwell as discovering the electromagnetic field in order to make possible transatlantic communications. Such a philosophy wipes out all distinction between pure and applied science, and it values pure science only for the fact that it may turn out to be useful in the end.

The other line along which the new philosophy attacks the position of science is based on moral grounds. It insists that scientists should turn their eyes to the misery which fills the world and think of the relief they could bring to it. It asks whether on looking round they can find it in their hearts to use their gifts for the elucidation of some abstruse problem—as for example the counting of the electrons in the universe, or the solution of Fermat's theorem. Could they possibly prove so selfish? In this manner scientists are reproached for pursuing science for the mere love of knowledge.

Thus we can see the position of pure science today under the cross-fire of two attacks based on rather disparate grounds; forming a somewhat paradoxical combination—but one that is actually very typical of the modern mind. A new destructive scepticism is seen united to a new passionate social conscience; an utter disbelief in the spirit of man is seen coupled with extravagant moral demands. We see at work here the mode of action which has already dealt so many shattering blows to the modern world: the chisel of nihilism driven by the hammer of social conscience.

This is the lesson to be read from the scene of Europe. The destruction of our civilisation over large stretches of the Continent was not due to an accidental outbreak of Fascist beastliness. The events which, starting from the Russian Revolution, have ravaged the Continent represent on the contrary one vast coherent process of upheaval. Great waves of humanitarian and patriotic sentiments were its prime impulses, and it was these sentiments which released destruction over Europe. Savagery is always there lurking among us; but it can break loose on a grand scale only when moral passions first smash up the controls of civilisation. There are always some potential Hitlers and Mussolinis about, but they can gain power only if they succeed in perverting moral forces to their own ends.

We must ask, therefore, why moral forces could be thus perverted; why the great social passions of our time turned so readily into violent and destructive channels. The reason seems clearly that there was no other channel available to them. A radical scepticism had destroyed popular belief in the reality of justice and reason. It had stamped these ideals as mere superstructures; as out-of-date ideologies of a bourgeois age; as mere screens for the interests hiding behind them; and indeed, as pitfalls of confusion and weakness to anyone who would trust in them. No longer was there a sufficiently strong belief in justice and reason in which to embody social passions. And there grew up on the Continent a generation full of moral fire and yet despising reason and justice. Believing instead—in what? Well, in what there was left for them to believe in. In power, economic interest, subconscious desire. Such were the forces left for them to rely on; and these they accepted as the

ultimate reality to which they could entrust themselves. Here they found a modern, hard-boiled, tough embodiment for their moral passions. And the highest hopes of humanity were thus embodied in violence. Social sentiment was turned into hatred and the desire for the brotherhood of man into deadly class war. Patriotism was turned into Fascist beastliness ; the more beastly the more patriotic the people who had gone Fascist.

I may quote here Mr. Atlee recently describing the most urgent need in Europe at the present time. 'We need,' he said, 'a conception of justice not as a will of a section, but as something absolute,' and a leadership 'which will lift people up from a mere longing for material benefits to a sense of the highest mission of mankind.' Mr. Bevin has spoken in a similar fashion when, facing the starving masses of Europe, he talked of a 'spiritual hunger which is even more devastating than physical hunger.'

But alas, the doctrine which had been so effectively hammered into our heads by the leading philosophical movement during the last fifteen years had taught us precisely this : that justice is nothing but the will of one section, and that there can be nothing higher than the longing for material benefits ; so that to talk about higher missions is just foolishness or deceit. No, the spiritual hunger of Europe will not be satisfied so long as we follow the leadership of those—whether on the Left or on the Right—who teach that material interests alone are real. The most urgent need of the day is to oppose this philosophy with all our might and at every point. To us scientists it falls to attack it in connection with science. The most vital service we owe to the world to-day is to restore our own scientific ideals which have fallen into discredit under the influence of the modern philosophical movement. We must reassert that the essence of science is the love of knowledge and that the utility of knowledge does not concern us primarily. We must stand up and demand once more for science that public respect and support which is due to it as a pursuit of knowledge and of knowledge alone. We must reassert the claims of science as part of the claims of scholarship and demand respect for all scholarship. We must re-establish also the claims of academic independence and of academic freedom. We scientists are pledged to a higher obligation, to values more precious than material welfare ; to a service far more urgent than that of material welfare. Europe can be saved only by the spirit. Our duty is to keep faith with the spirit in science.

How sharply the spirit of pure scholarship is opposed to the claims of totalitarianism has been sufficiently proved on many cruel and terrible occasions in contemporary history. Universities which upheld the purity of their standards under totalitarianism invariably had to stand up to harsh pressure and often to suffer heavy penalties. The whole world recognises to-day its debt to universities in Poland and Norway, in Holland, in Belgium and France, where such pressure was withstood and such penalties were endured. These places are witnesses to-day to the convictions underlying our European civilisation and hold out the hope of a genuine European recovery. And where, on the contrary, universities have allowed themselves to be bamboozled or terrorised into compromising their standards, we feel that the very roots of our civilisation have been marred. In such places our hopes for the future burn dark and low.

The world needs science to-day above all as an example of the good life. Spread out over the planet scientists form even to-day, though submerged by disaster, the body of a great and good society. Even to-day the scientists of Moscow and Cambridge, of Bangalore and San Francisco respect the same standards in science ; and in the depths of shattered Germany and Japan a scientist is still one of ourselves, upholding the same code of scientific work. Isolated though we are to-day from each other, we still bear the mark of a common intellectual heritage, and claim succession to the same great forerunners.

We must demand the revival of international scientific life, as part of the restoration of reason and civilised human intercourse in Europe. We need no official delegates nor the help of any official agencies. Let the United Nations simply extend the privileges of diplomatic passage—or at least the privileges of the press—to scientists and scholars all over the world. Let them but give us scientists freedom to travel as we please through Europe and we shall restore within six months a close and intensive collaboration of all scientific workers in Europe. We shall re-weave once more at least this part of the destroyed European fabric. By a single cut through red tape a vital aspect of European civilisation would be restored to life once more.

This we must demand ; and if governments will not listen to us, we shall at least have made our position clear and formed a rallying centre for other forces advancing on parallel lines. We shall stand ready to support other demands for the resumption of European intercourse and the restoration of European standards. If such demands sound Utopian to-day, this only proves how urgent they are ; how widely we have fallen away from what even a short time ago were normal requirements of civilised life. It only demonstrates once more what dynamic antagonism the claims of our academic tradition can exert against oppressive governments in our days.

Such is my conception of the relation of science to the community in our days. In the great struggle for our civilisation science occupies a section in the front line. The movement which is undermining the position of pure science is, in my view, one detachment of the forces assailing our civilisation. I know perfectly well that these forces embody some of the most penetrating thoughts and some of the most generous sentiments of our days, but that makes it only the more dangerous in my eyes. We shall have to fight, in this battle, to our sorrow, some of the best motives of human progress. But we cannot afford to turn aside for them. The easy wisdom of the modern sceptic, robbing him and his followers of spiritual guidance and setting free so much untutored enthusiasm, has cost us already too dearly. Whatever scorn be poured upon us by some who find our faith in pure science old-fashioned, and whatever condemnation by others who will think us selfish, we must persist in vindicating the ideals of science. We must fight for their complete restoration to their original position.

Europe is in mortal danger to-day through a state of all-persuasive suspicion. On the Continent few political parties feel safe with their opponents holding the Ministries of Police or War. In countries under dictatorship any opposition is rigidly presumed to be treason. The aggregate of all these suspicions is embodied on a colossal scale in the tension between Russia and the West. Yet I can see little wickedness abroad and much goodwill everywhere. If in spite of this we are in mortal danger from general suspicion, it is because so many people earnestly believe to-day that only violence can achieve results that are worth while. The nobler their purpose the more profound the perversion, and the greater its menace to civilisation. The only hope for Europe is that its leaders may become converted once more to a belief in solutions by reason and justice. No triumphs of applied science can help us ; no improvement of the atomic bomb, nor even a defence against the bomb ; not jet-planes outpacing sound ; nor new vitamins or penicillins—not even with the remedies of cancer and tuberculosis added to them. But wherever we reassert the spirit of pure science and pure scholarship we shall help to revive also the spirit of reason and justice, and shall thus supply an element which is indispensable to European survival and make a start along the only path towards recovery and safety. We may not succeed. But even so, at least, by proclaiming our true philosophy we shall face the disasters of our time in a manner which may transmit to later ages the true mission of science.

Prof. J. W. Munro

Some years ago I took up the study of an insect community which maintains its existence in the wharves and warehouses in the docks of London. It is a small community comprising somewhat over a hundred species, nearly all of which are exotic and many of which depend for their persistence in our ports on reinforcements from tropical or subtropical climes.

The scientific problems that community presents are how it maintains itself, how its population fluctuates and how from time to time its constitution varies. In that community, now one species seems to be dominant, now another. Then again the species making up the community contrive to live in apparent close competition with one another, feeding on such varied commodities as grain, dried fruits, cocoa beans and tobacco. Some are closely associated with other animals occurring in the docks such as the little Ptinid beetles living in rat droppings ; others live on mould fungi growing on such commodities as copra and nutmeg or on the moulds growing on wine kegs. Some species are parasitic on members of the insect community itself. Here, in fact, is an insect community, more or less closed as the plant ecologists would say, presenting endless scientific problems. The mode of feeding and nutrition of some of these insects is providing exciting research problems for the physiologist, the rise and fall in numbers of the more dominant species provides interesting material for the students of ecology or population problems, and the systematic study and classification of the genera and species in the community has recently afforded some years' interesting work for students of systematic entomology. The activities of the grain weevils living in grain in bulk, resulting in the creation of hot spots and later in rises in the temperature and humidity of the grain, present an interesting and not too easy problem for students of the physiology of storage, and only to catalogue the many problems this little community presents would more than occupy all the time at my disposal now.

I may have said enough to persuade you that here is a field of work presenting almost endless problems of real scientific interest calling for fundamental research of a high order. So far then, for that insect community and the purely scientific problems it presents.

There are other problems, as to which, for my part, I am indifferent whether you call them applied scientific or economic. To me these problems too are interesting. Here is an insect community maintaining itself by taking toll of the perishable goods which the human community acquires and stores at cost and labour from all quarters of the globe. How heavy that toll is it would be interesting to know, but measurement is difficult and I must be content to quote a single example, the only precise figures known to me. These have recently been reported by Dr. F. P. Coyne, lately Director of Storage, Department of Food, India, and relate to wheat storage. Dr. Coyne estimates that three million tons of wheat are annually destroyed by grain weevils, and his figures are confirmed by an estimate made by the Imperial Agricultural Research Institute which appraises the annual loss at 5 per cent., or more than three million tons.[1] These estimates relate to loss by destruction of the commodity, but that loss is by no means the only one, nor, in some circumstances, is it the most important. Some years ago the importation of Australian dried fruits —sultanas and raisins—into this country was all but abandoned because the presence of caterpillars of the moth *Plodia interpunctella* made the fruit unmarketable. That difficulty was overcome at a cost, including the research work done, of £30,000. In three years the saving effected was £150,000, and when the war broke out Australian dried fruit was top of the market. Now that saving represented not the value of the fruit saved from the jaws of the caterpillars, but the value of recovered prestige and markets. I could cite other instances of the same kind but that one may suffice to show that the losses caused by insect infestation are both direct and indirect, and in some circumstances the indirect loss may be the more serious. Incidentally, had the importation of their dried fruits into this country been abandoned the Australian vine growers—mainly ex-service men of the last war—would have been severely hit. They were given land for cultivation and took on vine culture as a livelihood and that livelihood was threatened.

That, then, is the economic problem presented by our insect community, and obviously it poses another question—can these economic losses be reduced or controlled?—and here we find the applied scientific problem.

[1] *Principles of Cereal Storage*, by F. P. Coyne. Government of India Press, 1945.

The problem of insect infestation of stored products is not new or recent, and when I tackled it as it related to dried fruits, fumigation of infested fruit was already widely practised—but, and this is important, its practice was wholly empirical. Once again we had to resort to research, and once again we went back to first principles and once again the field provided scope for research of a high order. That work over the past fifteen years has been published and I need not refer to it in detail. I may, however, venture the statement that the work of Dr. Page and Dr. Lubatti has given this country a leading position in the scientific study of fumigation.

One particular piece of work on fumigation is, I think, relevant in this discussion. One of the most widely used fumigants in this country is HCN. It is poisonous stuff, and when its use for the destruction of bed bugs, during slum clearance, became more general, some regulation for its use became desirable. The scientific basis for that regulation was lacking until Dr. Page and his colleagues provided it by applying their research results to the study of fumigation of dwelling-houses. Here is a useful illustration of the relationship between fundamental research and public health legislation.

Our work in this field, at first financed by the Empire Marketing Board, was, after the untimely demise of that body, financed in part by the aid of industry and in part by the University Grants Committee, and I should like briefly to comment on that.

In the first German war, at the request of the Board of Agriculture, the Royal Society set up a committee on Grain Pests. In its last report that committee recommended that its work should be continued and expressed the view that the recently established Department of Scientific and Industrial Research should provide for it. No action was taken. From 1929 to 1931 our work in this field in the Imperial College was financed, as I have said, by the Empire Marketing Board ; then, for a year, it was assisted by the Imperial Council of Agriculture Bureaux. After that, although Sir Henry Tizard—then Rector of Imperial College—and myself urged the Department of Scientific and Industrial Research to assist it, no Government support was forthcoming until late in 1938, when an appeal was made by a committee representing the railway companies, the warehousemen and the National Farmers' Union to the Ministry of Agriculture, and ultimately D.S.I.R. was persuaded to take action. Then came the war, when the protection of our food reserves was vital, and to-day we have a special laboratory—the Pest Infestation Laboratory—of the D.S.I.R., devoted to research on infestation, and a special division of the Ministry of Food—the Infestation Control Division—concerned with practical control measures. Recently, under the ægis of the Emergency Economic Committee for Europe, a conference on food infestation was held at which delegates attended from Britain, France, Belgium, Holland, Denmark, Norway, Greece, Yugoslavia, Turkey and Italy, as well as from the Control Commissions in occupied territory and from UNRRA. The conference reached unanimous conclusions on the seriousness of infestation in all the countries, the need for making known cause and effect, and the means of preventing and combating infestation.

I briefly mention the history of the development of this field of work, not to have a hit at the Government, but to call your attention to a matter of considerable interest, in these days of planned research and high-powered Government laboratories. The insect community in our warehouses is now receiving attention—pressure of war has, I think, ensured that—but where, until the war came, was the public conscience in this matter? The human community was ignorant of, or ignored, one of its quite important problems ; and here is the point I want to make, namely, that when the war came and action against infestation of food reserves by rodents and by insects became imperative, timely action was made possible only because the Universities of Oxford and of London had allowed two scientific workers, Mr. Charles Elton at the Bureau of Animal Populations and myself at Imperial College, to follow our bent and study certain scientific problems because we were interested in them. It was solely because of that, that when war broke out, teams of trained men and laboratories especially equipped for the work were available to Government and the community.

I am not worried about what I might call the economic aspects of this research : what I am concerned about is how members of the universities can be free and be assisted to carry out the research in which they are interested, primarily because it presents a scientific problem, and only secondly, if at all, because it may provide a solution to a practical problem. When I approached the Empire Marketing Board for assistance in this work in ecology, I did not profess, or at any stage tell them, that our work would help to solve their practical problems, but appealed to them purely on scientific grounds.

Then there is another aspect which interests me. The particular kind of biology which it is my duty in the University of London to teach is best illustrated by stating the kind of problems that it is interested in ; and the problem they are mainly interested in is old, and is best described by Darwin in a chapter of the *Origin of Species*, when Darwin took a tangled bank of brambles, with its insects and other animals, and tried to consider what what were the factors, agents, or whatever you may care to call them, which had produced that biological community. That is the work which is, as it were, the fundamental science which it is my function at the Imperial College to teach. Here, there and everywhere it touches particular problems in economy, and has practical importance.

I am not concerned that the applied aspects of that work will be neglected. I am concerned that entirely free and independent work in the universities shall be continued, and on a sufficient scale to make the workers engaged in it feel that in tackling a long-range problem, while perhaps they will not ultimately solve it, they will make a substantial contribution to the new knowledge concerned. That is one of the new problems we will be faced with in the near future. I mention it because there are various aspects of university finance which in my view have to be solved. It would be relatively easy for me to raise funds for

fundamental research by proposing to the Government certain fundamental aspects of applied problems, but I am likely in these days to be competing in the future with some government laboratory. The proper source for me to go to is the University Grants Committee, and one cannot quarrel with their decision; they are averse from the ear-marking of the grant to the university. But it seems to me that here is a question that we have somehow or other to solve : in other words, are we going to ask for the ear-marking of university grants, and in doing so are we risking the danger that we may come under too close direction? I do not object to some government direction, but I do object to too close direction by Government Departments which are, and must be, primarily concerned with the particular application of research to the community.

Prof. Sir C. D. Ellis, F.R.S.

Fundamental Research in Relation to the Community : the bearing of Atomic Energy on this question.

RECENT discoveries have come so quickly, the progress of the work kept so secret and announced so dramatically, that the problem of the proper guiding of research on atomic energy assumes a paramount position in this inquiry.

I have been asked to introduce this subject for your consideration and perhaps the major difficulty is to approach the problem in the right light. On the one hand we are told that the use of atomic power for war means the end of civilisation; on the other that its use for peaceful purposes ushers in the millennium. The warlike aspects I shall not discuss here. But the belief in the millennium must be examined. If this is only wishful thinking it is certainly excusable in a weary world depleted of resources, but it is none the less dangerous. Should there be even some little truth in these hopes, however, then not only must we prepare for these changes, but we may take heart in our present difficulties.

I hesitate to be dogmatic on these matters. All my instincts lead me to be optimistic and to speculate on exciting possibilities, but if the tenor of what I have to say is moderate in tone it is because I am sure great harm will result if too exaggerated a view is taken of likely developments.

I am not going to argue the case for the need for active fundamental research on nuclear physics ; the need is too obvious. Progress can only be assured if we have an ever-widening basis of fundamental knowledge. I will assume that this point is conceded and we agree that pure research must have first priority.

If with this one remark I leave this vital point it is only because I have no wish to knock at an open door, and further because I wish to spend the time allotted to me to sketch in the background against which we should view the whole subject. This background to my mind is formed by the advantages to the community that may result from the application of these new discoveries for the services of the community. Research is good for its own sake ; it is the purest intellectual pleasure that is known ; but from the standpoint of the community we must consider the value to the community as a whole, not just the pleasure it gives to a few scientists. The spiritual value of research has been emphasised by Professor Polanyi in terms with which I am sure everyone is in full agreement. It is necessary to give due weight to these points that we feel so deeply, but we must also look on the other side. I propose therefore to review briefly what are the immediate practical results of these new discoveries.

The outstanding achievement is the development of what is called the pile. In this, for the first time, we see realised a large-scale nuclear reaction. And please excuse me if from the pure standpoint I say ' nuclear ' instead of ' atomic.' The popular press has always used the word ' atomic.' Its possibility depends on a curious phenomenon shown by certain heavy elements among which are Uranium and Thorium. This is the phenomenon of fission. A uranium nucleus, that is, the centre part of the uranium atom, can combine with a neutron to give a violent reaction that splits the nucleus into roughly equal parts and emits a great deal of energy. But still more important than this energy emission is, that whereas the reaction requires one neutron per uranium nucleus to cause fission, in the resulting break-up several neutrons are emitted. There is thus a gain in neutrons, and if the process can be caused to take place sufficiently often the total number of neutrons in the pile can be built up to a very large figure.

Nuclear reactions have been known for a very long while, but it is the existence of the neutron that makes them possible on an industrial scale. The nuclei of atoms are surrounded by a protective electric field which except in special circumstances will repel the entry of other reactive agents, that is, other nuclei. The neutron, however, is uncharged and the process of combination between neutrons and nuclei is as straightforward as that between any two substances in a chemical reaction. In the past the problem has been to achieve a supply of neutrons for this purpose, and only minute quantities could be provided, by means of elaborate apparatus, but now that the discovery of the process of fission, and its utilisation in a self-maintaining chain reaction in a pile, has led to a practical method of obtaining a high density of this essential requirement, nuclear chemistry on an industrial scale is a practical possibility.

The details of how a pile works and how it is built up are technical, and most of the information that is now public is not strictly relevant to our present inquiry. It will suffice to say that a pile consists essentially of rods of uranium spaced in the form of a lattice in some light substance, the moderator, such as carbon or heavy water. The size of these piles depends upon the type of moderator used or the particular type of material used for the fission reaction. There are great developments possible and it seems likely that in the future, using special heavy elements, and for example, heavy water as a moderator, the physical size can be kept quite low.

We are more concerned to-day to consider what this discovery means. In the first place, as I have already said, it means that nuclear chemistry is possible on an industrial scale. Large supplies in the vital nuclear reagent, neutrons, can be made

available, and we are undoubtedly at the beginning of a period of nuclear chemistry comparable in the possibilities of its development with that of industrial chemistry. To speculate on this is, as Lord Rutherford used to say, 'drawing blank cheques on eternity'; but I may at least point out to you that one immediate effect will be a widespread availability of radio-active materials of all atomic weights. The therapeutic uses of these will be manifold and their value for research as indicators and aids to the tracing of biological and physical processes will be immense. I would like to emphasise particularly that this aspect should not be forgotten, and that what we may gain from these facilities may ultimately prove to be among the greater benefits resulting from those discoveries.

I come now to the question of power. This has seized the public imagination, and rightly so, for the availability of power is one of the most important factors in industrial development. I have referred to the pile as the realisation of a nuclear chemical reaction on an industrial scale, but in the process a great deal of energy is released. It is necessary to keep the pile cool by circulating water around the reacting uranium slugs and this cooling water carries away the heat liberated in the process. The point at issue is to decide whether this heat can be used. Let us assume that all the difficulties are overcome and the heat produced in the nuclear reaction is made available in a suitable form, say, as steam. If this could be done it would then be possible to build a pile of relatively small size which could produce steam at a rate corresponding to 300,000 kilowatts. Does this mean that power is going to be extremely cheap? That, of course, is the question. The matter can be looked at broadly in this way. The nuclear fission pile, with its water cooling and production of steam could replace the boilers in a modern power plant and would render unnecessary the continuous supply of fuel. But that is all that it does do; it is still necessary to have the turbine layout and the dynamos, and the machinery and equipment for distributing the power. In fact, it appears to me that the situation as regards the cost of producing the power will be very similar to that of utilising water-power. I find it hard to believe that when nuclear piles are finally set up to produce power, the power will be any cheaper at the site than it will be at, say, the Niagara Falls. However, there is just one and very real difference—we can now have a Niagara Falls wherever we like. This is a stupendous advantage. It means that, in the future, industry has not to go to the coal areas, or, alternatively, have the coal transported to it; any particular industry can choose the place best suited for its own development and be assured of the same facilities for power as if there were ample water-power conveniently situated immediately in the vicinity. There is in principle no fundamental difficulty in producing power in quantity in any place whatsoever as long as it is sufficiently accessible to permit the ancillary machinery to be brought there. We may further contemplate that in round figures the public supply of electricity in the United Kingdom is 3000 million kilowatt hours per month, that is, at the rate of four million kilowatts. Nuclear piles are being built at about one-third million kilowatt size, so that the possible contributions, at a place of our own choosing, might well be important.

I am sure that it is this aspect which must be particularly borne in mind in planning how we can utilise this new discovery, and the implications are so obvious that it is unnecessary for me to underline them. It may, however, be of some interest to look a little into the figures. We cannot expect the new developments to occur rapidly because the initial cost of working out the production of power will be large and the capital cost of the uranium pile will be considerable, but we can get some idea by considering the figures published by the Central Electricity Board for 1938. With coal at 20*s.* 3*d.* a ton the fuel amounted to 28 per cent. of the cost, capital charges 28 per cent., salary and wages, repair and maintenance 10 per cent., profit 34 per cent. With the generation of heat from nuclear processes it will be unnecessary to supply any coal —instead, uranium will have to be provided, but the rest of the installation will be just about as costly. It would appear, therefore, that however economically the pile is built, it is unlikely, in the near future, to effect a very great reduction in cost.

Among possible developments that have been mentioned in regard to the use of nuclear power have been the driving of ships or automobiles. I will not say that this is impossible, but let us consider for a moment using nuclear energy for generating the steam to work the turbines for a large ship like the *Queen Mary*. The boilers might be smaller and certainly the fuel space would be saved. There will be, therefore, an immediate gain in space and in tonnage that can be carried. Since the *Queen Mary* carries 6300 tons of fuel it seems that, after due allowance has been made for the weight of the nuclear energy power plant and all the massive protection necessary to protect people from the radio-active effects, there would be a considerable net gain in extra carrying capacity. This is an important gain, but whether it would really be advantageous without a completely redesigned ship is doubtful. Taking into account capital cost and complication, I think it is a matter that lies far more in the future than the generation of power on the site of an important industrial centre.

The same considerations apply with still more force to the possibility of driving motor vehicles by nuclear energy. It seems to me that it will be a long time before any such method can rival the convenience of the petrol motor. If these new sources of power are to have any effect on road transport, I consider it far more likely that the ample provision of industrial power will lead to the production, by methods of ordinary industrial chemistry, of special fuels as an alternative to petrol. If petrol is still in good supply, I feel that it will not be difficult for automobile engineers to keep ahead in convenience and reliability of anything that can be produced by these new means.

Lastly, we must not forget that the supplies of uranium are no more unlimited than those of coal or of oil. Accurate world surveys of this commodity are not available because it has so recently achieved its present importance, but it may be worth considering that, roughly, one pound of ordinary uranium has about the same heat content, from the standpoint of the availability of heat energy, as 10 tons of coal. It will, however, probably be some considerable time before the

uranium heat content can be used as economically. The present production of coal in England is of the order of 200,000,000 tons per annum and therefore, quite apart from the doubtful efficiency factor, it would require some 10,000 tons of uranium a year to equal this, a figure that, at present, is quite impossible. This illustration is merely a warning that we must not anticipate in the foreseeable future that an unlimited source of power has been put before us.

I feel, therefore, that in looking at this matter, we should view the future with considerable caution. We must carefully avoid any suggestion that these new discoveries have made the whole problem of power a simple one, or that unlimited power can now be supplied. A great deal is written that we are entering upon the Atomic Age and this is undoubtedly true if we are only clear what we mean by the Atomic Age. As I have said, it does mean that nuclear reactions can be carried out on an industrial scale with all that that entails in the availability of radio-active material with all its manifold uses. It even means, if it is ever convenient, that we can change weighable quantities of one element into another element. But above all the point on which we should focus attention is that it gives mobility to the production of power. No longer is a country with ample water-power specially favoured by nature. Any country that can master this new technique and can obtain the uranium, can in time put power-stations in the position most suitable for the development of its industries. This is the great fact and this is the point which is so important for planning in relation to the community. It provides a new degree of freedom in the planning of industry and this fundamental, if less spectacular, advantage is the point on which we should concentrate at present and reserve for later consideration the possible utilisation of the many features that will appear out of this new mastery over the physical world.

Taking a cautious and sober view, therefore, it is abundantly clear that even our present knowledge is sufficient to permit practical developments that can prove of immense value to the community. But these will only be the beginning, these first attempts will be crude and immature. We must not be blinded and thrown off our balance by the novelty of these developments. The possibility of their realisation should be only an encouragement to progress further; the benefits that result from them must not be considered an end in themselves. And so I shall end at the same point as I began—the need for fundamental research. It is only by our advances here that we can obtain a firm base for securing the advantages that lie in the distant future. The substance is there in the future and the key to it is fundamental research, but we must not forget this and grasp only for the shadow, the immediate application of our present knowledge.

Discussion

Prof. A. G. Tansley, F.R.S.—I would like first to consider the meanings of certain words constantly used in this discussion, and I do so because to be very clear as to what you mean by a word is often the best way to clarify thought.

The old traditional distinction between pure science and applied science has been attacked, and it has been said there is no real distinction at all, and that science is one, and so on. It has also become fashionable to use a word we have heard a lot this morning: 'fundamental' science, rather in the sense of the old 'pure' science. It seems to me that we ought to clear our minds on this point. We can all agree that certain branches of science are fundamental. For example, the analysis of the constitution of matter, the analysis of the structure of the atom—these are fundamental in natural science. On the other hand, on quite other planes, for example in biology, are we to distinguish a difference between fundamental science and non-fundamental science and, if so, how? It seems to me the problem becomes very difficult, and you get all grades of problems from what are unquestionably fundamental to to those which unquestionably are not. Take for example the problems Professor Munro was concerned with in the investigation of insect communities in food warehouses. He pointed out that the first attraction and motive of these investigations were towards those problems which interested individuals like himself, and that afterwards they turned out to have great application to practical requirements. But when he was pursuing these problems that interested him—and that is the difference—they were 'fundamental' problems. It seems to me the distinction is often difficult; on the other hand, the distinction between pure science and applied science seems to me exceptionally clear. The nature of pure science was lucidly expressed by our President in his opening address: it is pursued for the sole purpose of arriving at truth and acquiring fresh knowledge; whereas applied science is science which is used for the purpose of solving problems of practical importance to human beings.

Therefore we seem to me to have a perfectly clear logical distinction which cannot be gainsaid, and that is why I deprecate the replacement of the contrast between pure and applied science by the contrast between the fundamental and non-fundamental.

We are also told, quite truly, that it is a mistake to try to split up science, because it is one, and the great object of knowledge and investigation is concerned with the whole of nature, and with man's work as well. That is perfectly true, and should never be lost sight of. Science is a whole: that is what characterises it. It seems to me to be unified by *method*. The uniform method—of exact observation and comparison, of experiment, in particular of controlled experiment, which it is essential to apply wherever it is possible—that *method* of science is true of all science, pure or applied. It is a question of how you are going to attack a problem; not by guessing and the checking of that guess by somebody else's, which may be different, but by going to the phenomenon itself and looking into it by these well-known methods which have produced all the results that have been produced during the course of centuries. That is what unifies science, and it does not matter whether you apply them to the splitting of the atom or to sociological conditions in a great city. But that does not make the distinction between applied and pure science any less important, and

there, we may quite clearly see, the distinction depends not on method, but upon *motive*.

The motive of pure science is interest, keenness, the desire to find out how things work, and to define the truth in some agreed terms. The motive of applied science is to remove the practical difficulties in human affairs. In both cases the method you employ is fundamentally the same. These considerations are important for clarification, in order that we may think more clearly on the whole question. Pure science is necessarily the basis of the whole scientific fabric, because the original discoveries on which it is founded are unforeseeable, and cannot be provided to order or planned in advance ; and it is for this reason that pure science, under the conditions of modern life, must be adequately endowed, and must have money at its disposal which can be used by the people who spend their lives in making investigations in accordance with their own interests. They must have their freedom and they must have money ; and that money must not be controlled by any outside authority which is activated by motives of practical value.

It must be recognised, in other words, that the pursuit of pure science is a primary interest of the community which can only be fulfilled in that way. The endowments have to be assigned to individuals, who must be actuated by the desire to do research, and they must be able to get the money from some proper source. It is a difficult matter, but there must be a reasonable assumption established that the individual is qualified ; and the authorities who judge upon qualifications in the various fields of science must be scientific men themselves, because only they can know what are the qualifications and what can be done.

All this has nothing to do with a controversy, which is often carried on with unnecessary heat, about individual research and team work. It is perfectly true that the great discoveries have been made by individuals working alone—at least most of the great discoveries of other days ; but it is also equally true in modern science, and not only in applied science but in many realms of pure science, that experiments are often extremely complicated and laborious, and can only be conducted by teams of people working together ; and the practical question as to whether individual investigators should work alone, or whether teams should work together, depends entirely upon the particular problems involved and furnishes no difficulty whatever to scientific men engaged in the work.

Dr. Cecil Gordon.—While Professor Polanyi deplores the fact that he will have to oppose some of the most penetrating minds, and must upset sentiments, so also those whom he opposes deplore having to enter into dialectics with Professor Polanyi. In most of the day-to-day values in events around us, I think very little separates us. It is not easy on the spur of the moment to present a reply to so well-reasoned and lucid an address as that of Professor Polanyi, but I am afraid that his attitude springs from an emotional reaction that leads him to exaggerate where there is only a germ of truth.

At one stage he claims that those who regard Newton's and Clerk Maxwell's discoveries as being related to the historical context of their time are asserting that material interests alone are real. I have not yet discovered any exposition in which this is claimed. I think it would be fairer to say that they relate these discoveries to the historical context and the historical temper of the time. It has never been suggested, for example, that Newton was consciously developing his theories of gravitation because he was interested in navigation ; nor was Clerk Maxwell consciously developing electro-magnetic theories because he was interested in electrical power.

At another stage in his address he says that you cannot serve truth and material welfare. I should say, on the contrary, that (for example) Sir John Boyd Orr, in his position as Chairman of the Food and Agricultural Organisation, would have no difficulty whatsoever in serving both truth and material welfare. I do see what Professor Polanyi is getting at, but I am afraid he so exaggerates his case that he is knocking down Aunt Sallies of his own creation.

Professor Polanyi.—I appreciate this objective and interesting comment, but I think my statement goes to the heart of the matter, and is exaggerated only to the extent to which it is an exaggeration to say you cannot serve God and Mammon. You can, of course, but one or the other is your supreme master ; and that is the question.

Similarly when I spoke of ultimate reality, I meant it in the philosophic sense. Either it is historically determined by the course of material interests, or it is the true independent understanding of the intellectual powers of man. There, I think, lies the distinction.

(*The following communication from* **Flying Officer J. R. White,** *being a summary of a larger thesis, was read at the Conference by the Secretary of the Association, and was referred to the Council for consideration*).

MODERN science is so vast and complex that it would seem scarcely worth while even considering the possibility of a general solution for its manifold problems. However, there does seem to be a solution—a solution which might appear so obvious and self-evident that one might wonder why it has not been considered before, though different individuals have probably thought it over.

Let us consider just what the job of science is, and what it is trying to do. World knowledge may be considered as a beam of light. Then the job of science is to act as a prism and to separate this beam into its component colours in order to understand not only the colours but also the beam, of which the colours are constituent parts. The seven primary colours can represent the major branches of science. Each primary colour is then sub-divided until now we have a very large number of different colours. So far so good.

Science to-day has established millions of separate facts, some fitting into many combinations, some seemingly unrelated to existing knowledge and still others in direct conflict with present-day accepted theories.

It seems, therefore, that, just as the job of

science is to break down the beam of light into its many component shades and colours, in order to understand better its composition, so also should science attempt at re-blending these colours, this time with knowledge, until they form the same beam of light. In other words, science, having acted as a prism to break down light, must also act as a prism to re-blend the component colours once again into the same light.

Here, however, is where we find science sadly lacking. This all-important blending is left either to individuals or to bodies of individuals who, of necessity, have had to concentrate on one colour or at best have a limited acquaintance with some or all of the other colours.

Those great men who, by their very broadness of vision, have been able, in part, to join together the outlook of many sciences on one problem, have been the same who have contributed most to the progress of science. Such a task is beyond the power of most men, and yet out of hundreds of thousands of facts in several sciences, Darwin gave us one basic conception which tied them all together. Mendeleyev, too, gave us the periodic table in place of a veritable forest of seemingly unrelated and unsolvable facts. How? By bringing harmony and mathematics to bear on chemistry.

This, then, is the solution, so efficiently demonstrated in a small way during the war. Science must have a part of itself dedicated to the full-time job of assimilating all its findings, and the obvious, but overlooked, solution to this is that no one man or existing body is comprehensive enough to undertake such a task.

As every single science—fundamental, applied, social and humane has definitely a part to play in modern life, only a panel comprising a member of each science could be comprehensive enough to consider such an undertaking.

I therefore propose that there be immediately set up such a panel, which should be a full-time active centre for science. I propose that this panel undertake a review of existing knowledge, especially on those subjects obviously related to man and man's knowledge of himself and fellow men.

Furthermore, I propose that the panel be a forum for all branches of science.

Such a panel should be a small independent unit, to act as the keel of science, to which, and through which, all the institutes of research, as well as existing societies, might be joined voluntarily into one—a real workable unit. Such a scientific centre should in no way take over any of the duties or functions of existing societies or groups of societies, but merely act as a voluntary pool to unite them through service and mutual aid and trust into a mighty, efficient, authoritative whole.

Details of a suggested plan for such a unification of the sciences are submitted herewith for consideration. Copies are available through the courtesy of the British Association for the Advancement of Science.

PLANNED RESEARCH

FRIDAY, DECEMBER 7: AFTERNOON SESSION

ADDRESS BY THE RIGHT HON. HERBERT MORRISON, M.P., LORD PRESIDENT OF THE COUNCIL [1]

I AM very glad to be able to be once more with the British Association for the Advancement of Science, and I congratulate the Association on the admirable work which it has done. I think these meetings are very valuable, that this series in particular will be so eminently, and I wish the Association all success in the future.

During the war there has grown up a close working partnership between the Government, the nation's scientists, and industry. And I would emphasise the word 'partnership,' because it is one of the great things of which our nation is capable. However, it would not be well that scientists should be embodied in the government, and become automatic tools of government. Science and scientists must have an independent life and an independent existence of their own. So also I would say that industry must have a separate independent life and existence of its own, but not too much. That is to say, it must have a soul, a philosophy and a leadership; and above all it must have the right to tell His Majesty's Government to go to the devil from time to time. Everybody has that right. That is the test of democracy. Any country in which the citizen has not got that right is not a democratic country. That is a good definition of democracy, although it is negative.

Therefore I want industry and the industrialists to have their independent existence, even although they must be co-ordinated with the policy of the State, and there must be interrelationship between each other. The individual must have an independent existence, and the right to think and express himself from time to time without being shouted down. That also is necessary for a government, because if the government does not say what it thinks, and if Ministers have not got the courage to say

[1] Mr. Morrison had hoped to occupy the chair throughout this session, and expressed his regret at being compelled by other duties to leave on the conclusion of his address. Sir Richard Gregory Bt., F.R.S., followed him in the chair.

what they think, and if efforts are made to intimidate them to prevent them saying what they think, democracy cannot survive.

We have to build a partnership, co-operation and associated effort, between science, industry and government; and they must come together as free partners, and as free debaters and arguers in the spirit of co-operation and in the determination to make the partnership for the advancement not of science alone, not of industry alone, not of government alone, but the advancement of the well-being of the nation, and in the end for the well-being of mankind. Partnership in that sense is vital; and one of the problems of government, of collective life and of society, is to reconcile individuality—rugged aggressive individualism—with partnership, associated effort and co-operation.

It is one of my duties as Lord President of the Council to ensure that that association is not only maintained but is usefully developed in the service of the nation.

We fought the war with a clear and common aim.

Scientists were recruited and mobilised no less than the rest of us, and the aim of all research workers was consciously, deliberately and enthusiastically directed to winning victory, and that simplified organisation and psychological problems. We won, and we now find ourselves facing a peace no less fraught with difficulties, calling no less for high endeavour, requiring no less a spirit of high adventure and heroic courage in the process, demanding as much as war the ability and co-operation of scientists and technologists, and offering them even wider opportunities in the service of world economic development and security.

By closer association and sympathy with government, science will have, and is bound and ought to have, a social purpose. It will find its tasks and opportunities alongside the work of government. It will share and speed the common drive for social advancement. In facing with the Government the present tremendous economic and social problems, it will find an inspiration quite as great, I think, as it found in war; and a wise government, recognising the value of scientists, will provide full and practical encouragement of their work in peace.

Here let me say that we should have a right angle on this business of science and government. Sometimes the scientists are approaching that problem almost on the basis of 'Please, Government, be kind to us! Be charitable and give us a helping hand!' Sometimes the politicians say that we want to be kind to the scientists and to extend the hand of charity, and help them along. I do not like this atmosphere on either side. I want the Government, on the one hand, not to say that they will help the scientists, but to require the organisation of science in the interests of the nation. I want the scientists not to beg and to pray for a little helping hand and a few extras now and again, but to demand and assert the will of science to play its part in the organisation of the State, the work of industry and the progress of the nation. It is in that spirit that I speak of science playing its part and the government recognising the part that science should and ought to play.

For science has a vital contribution to make in the immediate future in its application to our need for production. For without increased production and productivity we cannot have social progress and security. You cannot have the cake and eat it, it has been rightly said; and that is very true. But I would add this, that we cannot eat the cake at all unless we produce the cake. Having produced as big a cake as possible we are entitled to fair shares of it, and indeed we must have fair shares of it, otherwise the cake will be left upon our hands and an economic crisis will ensue. But those shares can only grow if the cake grows. Man can only live in the end by toil and work, and he can only increase his economic reward and economic and social standard by advancing the totality of production. The great thing is that production should advance, but it is no good for production to advance unless at the same time we are seeing to it that the product is consumed and distributed, and fairly distributed, among the people who have contributed to its production. These are the two essentials of economics, and if they are remembered we shall be all right; but if one or the other is forgotten we shall be all wrong, for if we go on producing, and do not arrange for the product to be fairly distributed and consumed, we shall have so-called overproduction; and if we go on spending public money, and putting wages and the social services up without seeing to it that production is increasing to carry the increased demand, then we are going to be in a financial or economic crisis of another kind, but equally painful. The two things must march together. That is the business of government, and also it is the business of science, that production and distribution and consumption shall march together, otherwise difficulty is bound to ensue.

We have no reason to be ashamed of our record in pure science; but it is by no means clear that before the war we were equally successful in applying its results. Our experience in war has shown us that there is nothing essentially wrong with our ability in this respect, and that our trouble in the past

has been lack of boldness rather than lack of ability. Clearly we want our firms and industrialists to be research-minded, but they must become so in no narrow or selfish sense, surrounding all their work with secrecy, and appraising their results by the immediate marketable value of their output. Our advantage as a nation often lies in the development of whole industries, and it is in the public interest to think and develop on the widest possible scale.

Especially is it true in scientific research that work on a wider scale brings quicker and better development. It is in this belief that through the Department of Scientific and Industrial Research—a great department under a great leader, Sir Edward Appleton—the Government will give practical encouragement to the work of research associations.

So, too, it is restrictive and wasteful for a Government to take the extreme line of regimenting its scientists for research work on preconceived theories. In Germany it proved to be suicidal.

We can, however, do much to increase new knowledge by freeing workers in fundamental research from economic handicaps, and also to encourage them to pursue knowledge for its own sake. The right men, amply supported, will without doubt justify our trust.

In the wider field of applied science we must provide the right atmosphere and tools. We must provide a greater incentive to the scientists—the wide incentive of social progress instead of the narrower, though not irrelevant, incentive of profitable exploitation. We must assist by fixing priorities for development and application in the public interest, and in relation to the quickening of the economic plan. We must see to it that education provides opportunities for more scientists to be trained, and that there are assistants for our laboratories. For if we do not educate the coming generation of scientists and train them, then the number of scientists will fall, and science will be exterminated. We must look after the organisation not only of current action but of production of scientific personnel as well. We must see to it that education provides opportunities, as I have said, for more scientists to be trained, and of course we must have sufficient assistants in the laboratories. We must devote a fair share of our national income to scientific research, not an excessive share, but one that will produce substantial results. We must encourage the Civil Service and industry of all kinds to employ trained scientists and technologists to make the best application of the knowledge won by scientists working in the fields of pure research.

Scientific research will find its aims and inspiration inside the general national economic plan, and work to do in every section, industry, trade, the use of man-power, housing, nutrition, agriculture, and so on. The whole plan will be a master plan for scientists and for experts of every kind, and national problems and public needs will be the guides and targets for the endeavour of every section of the community in the forward national march. It will be a signpost, never a roadblock. In a world safe from war—we have not achieved that yet; we are on the horizon—in which the endeavour for true progress and security was common to all nations and all men, there must be complete freedom for scientists to exchange ideas, results and information, and the right to argue with each other; for even the pure scientists cannot work in isolation. To produce results research workers must co-operate, for they must take into account what is happening in their own field in other countries as well as in other laboratories in this country. Isolation can be good up to a point. It may even be productive of additional results, for a man living in isolation does not get his thoughts interrupted by other people cutting in, by irrelevant conversation and talk; but excessive isolation in the fields of science means that the pooling and fitting in of ideas is limited and reduces the total output; and therefore we need co-operative efforts among the laboratories and industries, and among the scientists of the nation, and finally among the scientists and research workers of the civilised world.

The need for the exchange of ideas and information goes outside the laboratories themselves. With a growing sympathy and collaboration between science, industry and government will go the need for closer contact and better information services. Science will take its place in the team, and good teamwork relies upon everyone in it knowing what the whole team is going to do, where it is going, and how it is going to get there.

That the Government is fully alive to the importance of science in every field of national endeavour was emphasised by sheer coincidence in both Houses of Parliament, and in a speech by the Prime Minister to the Royal Society, last week; and it is intentionally significant that the committee I have appointed to consider the policies which should govern the use and development of our scientific man-power and resources in the next ten years, includes, with its three scientists, one of whom is also a Civil Servant, an administrative Civil Servant, an economist and a business man; and it is a good combination, because the scientists have got to live with the Civil

Servants and with the economists, who are a troublesome race, but very valuable, and they all have to live with the business men. I have made them live together in this committee. I hope a divorce does not happen as a consequence.

I believe that the great constructive effort before the nation, approached with orderly planning and public spirit, will provide inspiration to every man and woman in the nation, whether they work with spades or formulas. It will ensure that their work is not wasted, but is used to rebuild Britain in a world of peace.

Let us not underestimate the complexities of the tasks that are before us. War has involved great destruction—deliberate, shocking, shameful destruction; but that is inevitable when war begins. It has turned our economic life upside down and inside out. We have ordered industry to do this, that and the other for the war effort, and now it has to go through the process in reverse, not necessarily going back to what it was, but becoming once more adaptable to the tasks of peace. Trade between nations has been upside down. Indeed, part of the purpose of the belligerents was to destroy and make impossible international trade. All sorts of things have been held up, disturbed, put upside down, and are now being turned inside out. The processes of organisation and industry, and many other things, we have to get right; and let us hope we do get them right according to the best of our ability. We are involved in a vast task. It is not as dramatic as the war was. It is not as simple in its purpose as the war was. Being a member of a war cabinet is a vast and terrible responsibility, but it is a simpler business than being a member of a government faced with the big tasks of adaptation, of reversion, of getting society going in the right way and in the right direction; and, moreover, the cause of freedom has come back again. The Government cannot order people about as they did. They have to be careful. The spirit of freedom comes up as it ought, and I do not complain. The right to argue reasserts itself, and I do not complain about that. Nevertheless, you have to get the nation going on proper lines to ordered ends, with circumstances more difficult than they were before.

These are problems that face us. They are difficult; they are terribly complex. Nevertheless, precisely because they are difficult, and precisely because they are terribly complex, they are very attractive. It is the life of danger, and adventure; but the aim is high, the purpose is a great one for our people and their well-being; and if there is danger and adventure, so there was in the heights of the war. This happens to be in the cause of peace. The British people are highly individualistic, and I would not ask that all should agree at every stage. But my ambition is that scientists, industrialists, politicians, ordinary citizens will see the vision, that they will conceive of the great purpose, and that according to their several lights and in their several ways they will try to pull together in the great partnership for the glory and the good of our country and the advancement of the world.

Sir Edward Appleton, G.B.E., K.C.B., F.R.S.

In opening this discussion on the planning of scientific research, I ought to say at the outset what I take the phrase to mean. You can plan a world-wide scientific experiment on cosmic rays with exactly simultaneous measurements at all latitudes, but I do not think our title was intended to refer to such a proposal as that. Instead, I am going to take the phrase 'planned scientific research' as meaning science studied deliberately and consciously with a view to application sooner or later.

To illustrate my interpretation of this phrase, I cite, as the supreme example of planned science, the development of the atomic bomb. Here was an example in which the greatest possible variety of scientific effort, from the measurement of target sizes of atomic nuclei to the design of the most gigantic engineering constructions, was integrated in the deliberate and conscious pursuit of a single practical objective. That the use of the objective, when it was reached, was for war-making does not matter. We can plan and integrate our science similarly for benevolent ends.

If that is accepted, what matters are two things: first the choice of our objectives, and second, the machinery of our planning, and I feel our discussion this afternoon must necessarily be related to those two very simple questions. What do you want to do and how do you propose to do it? I want you to notice I put the questions in that order and not the reverse order.

I think it is worth noting that originally invention and improvement of the arts of life and industry proceeded independently of science, or at any rate set the pace for science to follow and set problems for science to solve, and it was not until the nineteenth century that science notably led the way and practice followed.

Many penetrating minds have now recognised for years that science has these practical and social consequences. This is not a new idea; but during the war, when the period between discovery and use has been so strikingly contracted, the chain of events has been demonstrated for all to see. What is now new is that the public is sharply aware of the connection between science and its social consequences, and is concerned about it.

I would like to add one more word on this particular point. I have the privilege to be consulted frequently by young scientists starting out in life; and I find that whereas years ago such young people would be mainly concerned with

salary and conditions of service of the posts they were contemplating, the young people of to-day are also earnestly concerned with the question: 'What will be the practical consequence of my work, and whom will it benefit?' And I would like to put on record that in a number of cases the answer to that question has been the determining factor in the choice of posts.

Let us look at the present pattern of scientific research effort in Great Britain. It seems to me we can divide it into four main divisions—academic science, Government defence science, Government civil science and industrial science. Of course the resolution into these four classes should not be regarded too rigidly, since obviously the divisions overlap, as indeed they should.

It is important here, I think, to note the Government's participation in the scientific field. This arises from the more positive functions which Government exercises to-day. In the famous words of Graham Wallas, 'the Government has come to be engaged not merely in preventing wrong things being done but in bringing it about that the right things shall be done.' Government now considers that its function is to provide work, food and homes for all, and to these I would like to add two more, health and safety—safety from aggression. And to that end it encourages within its own borders planned researches on subjects of community and defence interest, the scientific results of which are available as part of the foundation of Government policy in many spheres.

Therefore, the one main problem we have to consider this afternoon is the relative allocation of effort between the four main divisions, academic science, Government defence science, Government civil science and industrial science; and, roughly, the relative effort will be proportionate to the sum of money and scientific man-power allocated to each division.

Let us take the first of the four. Academic research is conducted mainly in universities and other institutions of comparable status. It is conducted, or at any rate should be conducted, with the sole object of the advancement of knowledge, and I, for one, would like to see it as free of conditions as possible. I do not think, for example, that workers in universities should be forced from their primary objectives of advancing knowledge to follow the practical consequences of the by-products of their work. Those practical consequences should, I think, be seized on by others and, therefore, it seems to me that the only question of planning which arises here is planning so that enough money is available for present and future needs. That is all. Beyond that, the less planning the better.

But in Government defence research, Government civil research and industrial research, I think we have to plan our efforts for objectives, practical and social. In this connection, the D.S.I.R. has, from its earliest years, conducted research on many subjects of community interest. As people live in houses, travel on the roads, burn fuel and drink water, we do research on building roads, on fuel and water, and so on, and the results of this work are available to other departments of Government and to industry generally.

Also, the Department seeks to encourage, by way of the Research Association movement and otherwise, research in industry, to encourage a supply of trained research workers both for Government and industry, and also supports, by means of special grants, researches on specific subjects in universities. Much was done in this direction before the war. We ought to exclude the war period from our consideration, because during the war we, in the D.S.I.R., engaged our research staff and facilities mainly on defence science problems. I feel sure that, whatever we did before the war, there remains much more to be done; and to that end the Department has instituted, and already almost completed, the most searching surveys of the fields to be explored in all its own territories. In other words, we have tried to answer the first of my two questions: 'What do we want to do?' I do not think that there will be any difficulty, excepting shortage of scientific man-power, which will prevent us from doing what we are planning.

In all this work, objectively planned as it is, in civil and defence science, and in industrial science, there is a great danger of taking too short a view. During the war, the public has seen results flow from scientific effort quickly, so that there is a clamorous and uninformed cry for putting all our scientists to work, like so many ants, on a host of obvious short-range problems. I want therefore to emphasise the outstanding importance of what I would call objective fundamental research in the field of 'physical' science. By this I mean a long-range attack on basic generic problems. Usually this means that the objective is not immediate practical results but that of gaining physical, including chemical, insight into some basic phenomenon, such as corrosion, the oxidation of fats, the growth of large molecules or the electric state of the upper atmosphere. Often a basic attack of this kind is the shortest and most fruitful route to the solution of problems of practical importance, and when I use the word 'fruitful' I mean that, in doing fundamental research of this kind, you may be aiming for A and you get B instead, but even more important, you may throw out Z as a by-product which happens to be of far more practical consequence than A or B.

Therefore, to-day, with a wide range of problems that have to be solved, it is only prudent to devote a part of all scientific effort to fundamental research of the type I have indicated.

I will conclude by saying one word more on the subject of the use of the results of both academic and planned research. It seems to me there is a great danger of setting scientists on too high a pedestal. We often hear it suggested that we should do a particular thing scientifically, whereas in fact we really mean we should do it properly. This is a complete and most unfortunate misuse of the word 'scientifically.' I do not think the authority of the scientist extends beyond his own laboratory and spills over into other spheres. The scientist ought not to occupy any special privileged position as a citizen. He has, of course, a great responsibility for seeing that his results are intelligently presented to his fellow citizens. Once that is done, I think his place is the same as that of any other citizen. He must certainly not expect

to dictate how his work should be used, because I fancy a dictatorship of scientists would be just as bad as any other dictatorship.

Sir C. F. Goodeve, F.R.S.,

Formerly Deputy Controller for Research and Development, Admiralty

Planning and Organising Research

I SHOULD like to talk to you this afternoon about a few of the lessons of the war which can help us in the planning and organisation of research and development in this country. Before I begin, and in order to fix our ideas more clearly, I should like to consider first the two principal objectives which, as we have seen this morning, lie behind research work in general. There is the more idealistic one advocated so strongly by Prof. Polanyi—the advancement of knowledge; and there is the more material but nevertheless also idealistic one which has fired so many who have applied science during the recent decades of rapid development—the benefit of mankind, or more prosaically the improvement of mankind's physical conditions. During the past war this latter ideal, admittedly identified with the preservation of one's country, has been particularly strong. In times of peace, however, I believe that both these objectives are in the back of the minds of all scientists though in varying degrees and often hardly discernible.

These objectives and the terms fundamental, applied, etc., research are of course closely related and the best way of showing this relation is by means of a diagram (see Fig. 1). Supposing we lined up all of the research scientists in the country and sorted them out with those doing pure scientific research on the left, and those doing applied research on the right, we would provide ourselves with a scale in which the units were unit numbers of scientists. Also we would find a transition region in between where people are doing 'background' research or what Sir Edward Appleton has just called 'objective fundamental research,' that is fundamental research carried out in specific fields with a view to the ultimate application of its results to man's material needs. We would have great difficulty in drawing a line between the groups but less difficulty in deciding whether any two men were in their right relative position. More generally, of course, our scale refers to the types of activity of scientists; one man may divide his time over the scale.

The strength of the objectives behind the work of a particular group of scientific activity is plotted vertically and the solid lines show the relationship.

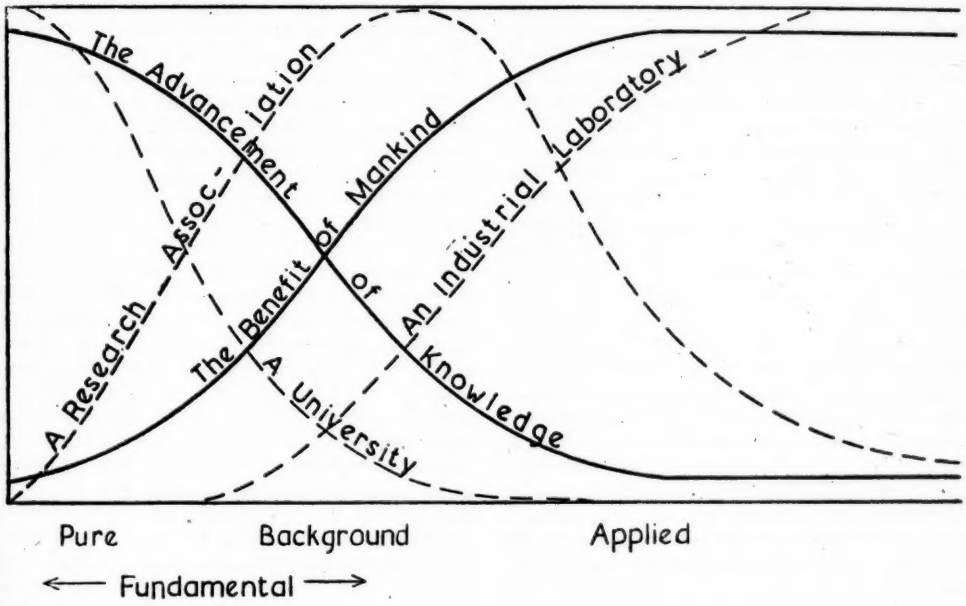


FIG. 1.—(*Full lines*) The two principal objectives of research as functions of the various research activities of scientists.
(*Broken Lines*) The distribution of effort in some typical research organisations.

Diagrams such as that shown are useful in many ways. For example, we can describe the distribution of function of universities, research associations and other research organisations and industrial laboratories by curves such as those shown by the broken lines. Here the ordinates would represent the fraction of the effort of any unit group in the abscissæ scale which is to be found in the laboratory referred to. The area under a curve would, if this was drawn to scale, give the total research staff activity in the organisation. There would, of course, be a big difference between the curves of individual laboratories; the curves of Oxford and Cambridge would lie to the left of the average and of Imperial College or Leeds to the right of the average. Some industries have no works laboratories and in such cases a research association curve may lie well over to the right of that shown.

Before I go on I should like to refer to one other

point—Prof. Polanyi has given as one of his arguments for pure research a need to keep up the standard of the ' scientific method,' which would be threatened if the whole focus of attention was on applied research. Others challenged this view. I agree with Prof. Polanyi; unfortunately in applied research and particularly in design, one proceeds largely by compromising between contending factors. You cannot make progress unless you do compromise and this process has no part in the ' scientific method.'

Is Planning to be encouraged?—The first question we must answer is : ' Is planning a good thing or a bad thing? ' Men here, as in other fields, are divided in their views, possibly because by planning they understand different things. Here, I mean by ' planning ' the direction of research effort into some fields rather than others, in order to meet the needs of the day or of the foreseeable future. Many people look askance at a planner, and indeed he can be a danger. For example, he sometimes tries to plan and organise pure scientific research, but fortunately he does not get very far. He too easily becomes a pseudo-politician and delights in work behind the scenes. Nevertheless, I would say our first lesson of the war is that proper planning and direction of background and applied research is not only a good thing, but is essential; practically the whole of the technical advances of the war have been made under a system of extensive planning and direction.

The subject of planning has also recently been examined in U.S.A. Dr. Jewett, until recently of Bell Telephone, said ' the most that a man can do is to provide a favourable environment for creative effort ' (*The Future of Industrial Research*, Standard Oil Development, p. 22), and C. E. K. Mees of Kodaks (*ibid.*, p. 48), said ' no Director who is any good ever really directs any research. What he does is to protect the research men from the people who want to direct them and who don't know anything about it.' On the other hand, our friends in the U.S.A. are embarking on the most comprehensive planning of all time, as is to be seen from Dr. Vannevar Bush's report to the President, *Science the Endless Frontier*, 1945. (It is a pity that this report is not easily obtainable in this country; it is a remarkable and important document.) Dr. Bush quotes our country as an example to be followed by the United States in planning science. I believe he considers us to be more planned than we actually are.

Everyone would agree that the points raised by Jewett and Mees are of great importance. They indeed describe the main difference between research and other forms of human effort, but the direction of research, that is the setting-up and running of an organisation for research, is much more complex than this, and it is here that our war experiences help us. Time and space permit me only to give a framework, but even a framework may stimulate thought and argument.

Objectives.—I put first in these lessons that a research organisation must be such that it can seek out and accurately ascertain objectives in the given field of activity and inspire every man in the organisation with the importance of these objectives. The difficulties in the way are too numerous to mention here; in the field of defence the major one is undoubtedly secrecy. The important fact is that the defence research organisations which were successful were only those which sought out the difficulties and found ways over and around them. The best method was to send research workers to study the problems at first hand, but there were many committees, symposia, etc., which were successful in clarifying objectives. By the end of the war even the doors to the military planners had been opened to scientists in order that they could examine the objectives for themselves. It was interesting to see the planning of the great operation beginning with D-day in June 1944. On the planning committees you could always find one or more scientists, and it is no exaggeration to state that they contributed substantially to the success of that plan. The application of this lesson to peace research will require a full knowledge on the part of scientists of the economic and commercial aspects of their work.

Collaboration with the User.—This leads on to the second main lesson, the importance of the right degree of collaboration with the user. In the first instance good collaboration is required to clarify the objectives referred to above. In this connection we made a useful distinction in the Admiralty between ' targets ' which were drawn up by the Naval Staff saying simply what they would like to have, and ' requirements ' which were agreed to by the research and production people as objectives for which there were reasonable prospects of successful achievement. Most of the research and development work went to meet ' requirements,' but some research and long-range thinking went on ' targets,' and when potential solutions emerged a ' target ' became crystallised into a ' requirement.'

The second important advantage of user collaboration is to ease the problem of ' selling ' the results of research. This of course is only another aspect of the first—if the user influence in clarifying the objective is strong, the result is generally automatically what he wants.

The user influence can, however, be too strong. I have seen too many cases in Government research where the user has cramped the technical man by condemning in advance a scientifically sound project as impractical. A balance must be struck, and as a ready rule one would say that the user influence should be moderate in the early or research stages and strong in the development stages.

While on this subject of the user relation I should like to point out two difficulties which will immediately crop up in any commercial peace-time application. Obviously user collaboration will fail if there is ignorance on the part of the user, a problem which in the Services can be got over if necessary by compulsion. For example, at one stage of the war sailors preferred a certain type of bullet protection to steel because it was thick; despite the fact that its protection was much less. But this preference fortunately counted for nothing since the Admiralty was in a position to enforce the use of steel. Where such compulsion cannot be used, however, the user must obviously be adequately educated if he is not to exert the wrong influence in any developer-user collaboration.

The other difficulty for which war experience can offer no help lies in the fact that the user and the organisation to which the research worker belongs are generally in a buyer-seller relation.

For example, it might at a particular moment pay a manufacturer to condemn his supplier of raw materials in order to force their prices down. Furthermore, one sometimes sees research and development effort being spent in an attempt to prove that a given fault lies on the other side in this buyer-seller relation. However, these difficulties will speak for themselves; all one can say is that the efficiency of our effort will depend on the extent to which we solve them.

The Research Team.—The third lesson of the war to which I would like to refer concerns the team system. It is well known that the complexity of modern equipment has forced the individual inventor into second place and that most of modern progress is made by teams. The organisation of these is a major task to a research director. He must see that each team contains in it a proper balance between the theoretical man and the experimenter, the scientist and the practical engineer, the inventor and the man with sound judgment, the various branches of professional skill, etc. He must pay attention to the personalities and aspirations of these men and he must provide the team, as Jewett puts it, with an environment favourable for creative effort. He must arrange that the work of the team is fully co-ordinated with the work of other teams, but in doing so he must not waste man-hours of effort, steer the new work into old channels, or weaken the incentive of members of the team. He must encourage impatience or even intolerance of inefficiency, of loose thinking and of other contradictions of the scientific method. At the same time he must encourage the members of the team always to learn first 'the other man's point of view.'

Ideas.—One could go on and develop this last section in many important directions, but I should like to refer only to two points. Perhaps the most common type of idea, and one which is very useful in industry, may be defined as a coincidence in a man's head between a piece of knowledge of what can be done and a knowledge of something that is required. Much of the direction of research involved arranging for a high rate of councidences, rather like a problem in reaction kinetics! But it can be seen at once that the gigantic task of converting the technical advances of the war to the benefit of mankind can be done by letting those who know what industry and people in general require into the secrets of the war advances and also by taking the men with war technical knowledge out into industry to get the knowledge of industry's needs into their reacting brains. Also it can be seen that it is important to disseminate information on the needs of industry.

The second point is that the war has shown unexpectedly that the man with specialised and long experience is weak unless he works alongside men who have new viewpoints and have not experienced the failures of the past. Blending of experience with inexperience is another job of the director of research.

Research as against Development.—Other lessons concern the balance between background research and development. Let me quote an experience regarding the new mine, which appeared towards the end of the war, working on the suction produced below a ship as it goes through the water. The Admiralty's scientists made such a mine early in the war. They were, however, more concerned with what we should do if the enemy also discovered it, because it was obviously an extremely difficult mine to sweep, that is to destroy harmlessly. A very thorough research programme was undertaken to determine all of the fundamental information. This was followed by the development of a sweep which at the time seemed the best possible although incomplete solution. The research cost was a few tens of thousands pounds, the development some hundreds of thousands. When the German mine actually appeared in operation our research coupled with a knowledge of German practice led to other cheaper and better solutions while the sweep developed in advance was not of great value. In other words, the research paid enormous dividends while the development barely, if at all, covered its cost. There were many other examples all proving the same point—it is an unacceptable risk not to back up development with research on a broad basis. We should include among famous last words the much too common question 'when you've got the information, what are you going to do with it?'

Priorities.—Finally I would like to say a word about priority. In the early days of the war, priority was determined by the Naval Staff at the Admiralty, representing the user. It soon became clear, however, that priority should be arrived at not only from the strength of a particular need, but also from the prospects of achieving a result to fulfill that need in the required time. While the time scale will in peace time be more generous, the principle, I believe, will have equal application.

Conclusion.—Of course many of the lessons of the war have long been known by the many people directing research in this country. The effect of the war will at least have been that these lessons will have been learned by *more people more effectively*. Provided we have and realise the need, there is no reason why the successful application of science in war cannot be repeated in peace.

Dr. E. F. Armstrong, F.R.S.[1]

Planned Research in the Building Industry

EVEN the self-styled practical men have been slow to realise the importance of understanding what they are doing and of having a theory behind their industrial activity. While there is much to be said for knowledge based on tradition and practical usage, older traditional industries give sad testimony that this method does not as a rule lead to progress in a world which should be making more and more use of science.

An industry in which tradition plays a very large part is building, in part because there are upwards of 85,000 firms—mostly small—engaged in it. The recognition of how little science there is behind building practice and, indeed, behind building materials, led to the formation of the Building Research Station located at Garston after the last war by the D.S.I.R., and likewise of the complementary body dealing with timber, the Forest Products Research Laboratory located at Princes Risborough.

[1] The late Dr. E. F. Armstrong was taken ill shortly before the conference, and his communication was read by Mr. J. W. Martin.

Both these organisations have made a very substantial start on the many problems that exist, their rate of progress being limited largely by their resources in staff and appliances and interfered with seriously by these six years of total war.

Building, first of houses, and then of factories, shops, schools, etc., has become one of the main problems of the Government. The need has led to the enlargement of the Ministry of Works so that it may fulfil the tasks allotted to it, and in particular to the formation of a large research department under the Chief Scientific Adviser, Sir Reginald Stradling, F.R.S.

The primary function of the department is to accumulate, on behalf of the Ministry, accurate knowledge on a scientific basis of all building materials and of all building processes as well as those other matters closely connected with building. The task is an ambitious one, so that the work requires careful organising and co-ordinating. The ultimate results will be incorporated in the work of the Ministry as a whole, in codes of practice, standards and reports showing clearly the correct answers to the questions which arise.

As a rule, much of the actual experimental work will be done in the Research Laboratories of the D.S.I.R., for example, the Building Research Station and the Forest Products Research Laboratory, but many of the ultimate problems can only be solved by building groups of experimental houses under the close supervision of trained observers.

Associated with the Chief Scientific Adviser is an advisory Committee of eminent scientists under the chairmanship of Prof. J. D. Bernal, F.R.S. Its full title is the Scientific Advisory Committee and it is working through three sub-committees :

1. Building Requirements ;
2. Building Materials and Structures ;
3. Building Industry ;

each of which is broken up as and when necessary into smaller panels so as to ensure that any particular subject can be discussed by a limited number of people who are closely interested in it.

It is the primary function of this Committee to discuss the problems of the Ministry brought to them by the Chief Scientific Adviser and restate them in terms which are as precise as possible, so that the necessary research may be undertaken in suitable institutions either of the D.S.I.R., at the universities, or elsewhere. Many of the problems associated with building materials have reference to the fundamental properties of matter and as such are appropriate for university research. As a rule, university workers are unaware of the need for these particular investigations and their bearing on national welfare.

When dealing with an industry like building, which is so largely based on traditional practice, it is not easy to break new ground. The behaviour of the traditional materials is known, which is not to say that much cannot still be learned about them. But there is often a vicious circle connected with would-be new materials ; for example, are they to be produced in quantity before they receive thorough trial or are considered for adoption, or are they to be passed on samples and mass produced afterwards, a practice which, though sometimes successful, has many dangers ?

We have grown to accept the traditional materials as final, and are mainly concerned with their production in the requisite quantity at the cheapest possible price. But this is not enough—we should not for ever go on accepting such unwelcome properties as shrinkage and creep, water absorption and the like, without understanding the fundamental scientific principles of such phenomena.

Any large research department dealing with practical problems has to handle day-to-day queries, many of which, for their proper answer, demand more or less research. Long before the full answer is available an emergency arises and someone with only a few facts at hand must make decisions to meet the difficulty in the best way possible. It would be preferable to wait until a staff of investigators unearthed all the facts, but that is not the way things happen.

Research on building must deal with requirements in the broadest sense of the word. These include physical and physiological requirements—problems of heating, ventilation, lighting and noise. Next come functional requirements, including the proper design of equipment and fittings. Equally important are social surveys directed not so much to present conditions but with the object of determining the conditions in the home which would give the best chance of development for the citizens of to-morrow. Lastly there is the question of education of the public at large so that they may be aware of what is being done and why, and of the occupiers of the houses so that they may take care of them and use them to the best advantage. Modern household appliances, for example, cookers, heaters, refrigerators, vacuum cleaners, etc., demand care and understanding of their use : too often they are grossly misused.

Research on materials mainly falls within the orbit of physics and chemistry : the subject is all-embracing, though as a whole most of the materials are inorganic, and it is surprising how many groups of these substances have escaped modern study from the scientists. There is an opportunity for a revival of interest in the inorganic and physical chemistry of the ordinary materials used in a house.

The building industry proper, that is, the building of houses with given materials to a given specification, is concerned first with that most elusive of all factors, human efficiency. With the advent of new materials and processes the operator must somehow be made a craftsman once again, interested in and enjoying his work, understanding it and trying to perfect it and the means of performing it. Processing study then becomes possible, with a view to reducing non-productive and wasted time by improvement of the site organisation. Costs and economics of all kinds and at all stages form part of the study picture.

The exact building requirements for dwellings is a matter on which there are many different opinions. The problem is best stated in the following form : what design and plan for the house and its fittings and of the communal facilities of the town results, for a given standard of amenity, in the minimum cost to the occupier ?

In taking account of costs only true costs are a a valid guide : they include rent, depreciation and

obsolescence, running costs, visible and invisible, e.g. the cost of domestic labour involved in cleaning, the cost of transport and delivery of domestic stores, as well as the invisible costs of travel to work and shopping. None of these problems is new, but few of them have been studied quantitatively.

Each of the physical requirements of buildings requires study, particularly from the physiological side, to ascertain with greater accuracy than is at present known the necessary physical conditions of temperature, humidity, radiation, air movement, which are conducive to health, comfort and efficiency. The relation of window size and even shape and position to the proper lighting of a room, as well as to the loss of heat through the window in winter, is an example of a specific problem.

A second aspect is covered by the term 'functional aspects of buildings' involving planning, fittings, furniture, mechanical equipment and the rest. This involves both social surveys and laboratory studies, including the placing of observers to live in experimental houses. It is surprising how much work is still required on fittings to ensure that they are the most suitable in relation to each other, to the layout of the dwelling and to all the various activities carried out in it.

The design of furniture, both for comfort and health, has been largely neglected by the scientist, particularly in relation to schools and offices. Here also the physiological factor is of importance.

Another way of stating the problem is the relationship of experimental methods used to determine what are the best ways of laying out the equipment of a house to achieve efficiency and reduce fatigue to those of social inquiries into existing conditions. Such inquiries will provide a measure of the degree of social reconditioning that the country requires.

The above remarks are given as an example of planned research on a very wide scale embracing all the sciences. During six years of war thousands of scientists have concentrated their efforts on researches mainly related to short-term problems of attack and defence. The same energies working with the same sense of urgency and high priority can now be directed to one of the most fundamental problems of our age, namely, the synthesis of suitable building for a modern civilisation.

Discussion

Prof. H. R. Kruyt.—In Holland we started before the war with the foundation of an organisation on a semi-official basis, and when we set up that organisation we studied the organisation of other departments of scientific and industrial research, and we have tried to get in Holland a somewhat similar organisation; but owing to the way in which our State is organised it was impossible to do it in an identical way, and our organisation is only on a semi-official basis.

Our organisation, for investigation in the field of applied science, has continued its work during the war and it is remarkable that that was possible. The only reason was that the Germans did not understand our organisation and when they do not understand a thing they deny its existence. This was a great advantage for us, for, in the first place, we were free from all co-operation with them and, moreover, they did not take workers to Germany; and we have worked during the war and hope to take up our tasks now as efficiently as possible.

We feel, nevertheless, that we are five years in arrears, and we do not know the literature that has appeared in other countries during that time; we have not achieved the enormous results which you have during the war, and we very much want co-operation with your country. During the last weeks several directors of our institutions for applied chemistry have been here in England, and, as far as they have reported to me, they have been well satisfied with the way in which you have received them here and with what they have seen and learnt from your institutes.

We hope to send a permanent liaison representative here from Holland to institutions for applied research in your country and we hope that in future there may be close association between the institutes of applied science in Holland and in England.

Sir William Larke, K.B.E.—As an industrialist I would like to add a small contribution by way of indicating some form of national machinery which, I think, would perhaps make available to us the results of research and stimulate our national research to still greater heights than those it has reached before. First of all, however, I would like to refer to this blessed word, planning.

It is many years since I became convinced that *laissez-faire* could never be a policy. It was a confession either of cowardice or of incompetence: cowardice because one was afraid to venture a decision or incompetence because one was unable to devise a policy. To provide fundamental scientists with resources and leave them alone, is not *laissez-faire*, because you plan to leave them alone and to give them all they want. Let us get away from this contemptuous attitude to the word planning, and realise that planning may well be the application of the scientific method as defined by Sir Edward Appleton, when he said that it really meant doing things properly.

I want to deal with a relatively narrow but, I think, vitally important aspect of our organisation in relation to planned research. I want to remind my fellow industrialists that the industrial revolution, which gave this country a flying start of a century, was the direct result of technological research and development persisted in to success by those who not infrequently pledged all their material resources to justify the faith that was in them. That is the lesson we industrialists to-day might take more fully to heart than we have in the last twenty-five years. We cannot expect to repeat the flying start of a century in a world so widely industrialised, largely as a result of our own teaching, but we can capitalise the lead our scientists have given and are giving us, by applying the results of their labours more rapidly than other countries.

The F.B.I. Committee on Industrial Research over which I have the honour to preside, has stated: 'To be first in the field of application is of even greater advantage to a country than to have been the birthplace of the discovery.' I think that would be generally accepted, even

although one might feel it was more honourable to be the birthplace of the discovery.

Our record in original research and discovery in the last 200 years, and particularly during the present century, is unsurpassed, if, indeed, it is equalled by any other country. If we are to maintain (let alone advance, as we all desire) our standard of life, we must lead the world with new industrial products. We are, in fact, in the midst of another industrial revolution based on new materials, the product of physical and chemical research. A new horizon is opening up with the possibility of harnessing atomic energy. The results obtained in this field of international co-operation have been achieved in five years' intensive work which most of those concerned would not have thought possible under a generation, and before the war many put at fifty years.

I was interested to hear of a debate on this subject on the adjournment of the House of Commons last Friday, and there, I think, the title of a new organisation suggested was the Central Council for Research and Development. The name is immaterial, but I want to indicate what such an organisation might do that we have not yet provided for. I suggest, in addition to retaining all the responsibilities of the Department of Scientific and Industrial Research, that this new organisation should be a national co-ordinating body for all scientific work and be the British counterpart of the organisation which President Truman suggested to Congress in his message on September 6 last should be set up in the United States. I accept the general constitution of the Council in its representative capacity, suggested by Sir Charles Goodeve, and I would add to his suggestions that it should be constituted of nominees of the Royal Society, the Federation of British Industries, the Associated Chambers of Commerce, the T.U.C. and the Government Departments concerned with research, such as the Colonial Office Research and Development Committee and other Government research bodies.

This body should be empowered to promote and finance through existing organisations, or to organise under its own direction, research into problems of a fundamental nature similar to those involved in the control and use of atomic energy, which, if solved, would have a far-reaching effect on the economic life of this country and the standards of life and the well-being of mankind as a whole, but which could not be solved so quickly by any one country acting alone for lack of research and financial resources for the purpose. Sir Robert Robinson pointed out the desirability of attacking the cure of cancer and tuberculosis in this way, to which might be added rheumatism and the common cold. The prevention and cure of either or all of these would have a profound effect on the well-being of mankind. There are many problems in the material field of far-reaching importance, such as the reason why alloys possess their particular physical properties. If we knew this, and the possibilities and limitations of the effect of alloying elements with metals, for example, the art of engineering construction might well be revolutionised. I remember Lord Rutherford saying that in a well-ordered world steel would be 900 times as strong as it is and the only reason that it is not is the presence of minute cracks in individual crystals ; and that someone would eventually eliminate those cracks. What a revolution that would mean in the physical well-being and material advantages which mankind enjoys !

The detailed responsibility for international collaboration in each field might be delegated to appropriate existing organisations by the National Council, which would provide the financial resources required. All research organisations and workers should be invited to submit to the Council any problems which they considered of importance but which, for lack of immediate interest or resources, they are unable to deal with. Such problems would be examined by an Advisory Committee of Scientists, which would recommend to the Council what (if any) action should be taken. In this way matters of fundamental importance, often neglected in the past because they were not of immediate interest or value to those who became aware of them as a by-product of their own work, would be examined and, if of importance, work would be undertaken under the aegis of the Council and financed by it. The Council would endeavour to expand and develop existing research facilities in universities, technical colleges, research associations and establishments, and if necessary set up new research establishments where facilities required were not available.

It would provide one central national source of information and, may I add, of inspiration relating to research, to which enquiries on any subject might be addressed. It would not supersede or interfere with any existing recording or abstracting authority, but by co-ordinating them would ensure enquiries reaching the appropriate body or obtain the reply and transmit it direct. At present the general enquirer is at a loss to whom to apply for help and information. If this country is to become fully research-minded, information and advice must be readily available at a recognised national centre.

The Council would publish reports and literature generally informative to industry and encourage enquiry from industry on problems connected with the organisation of research, and provide a source of information and inspiration, particularly to smaller industries. It is suggested that industrial concerns should be eligible to become subscribing members and that the subscription should cover the actual cost of the circulation of reports and literature. The executive officer should be the Secretary and the Chairman should be appointed by the Government of the day in the first instance for a period of, say, three years.

What we need in this country if we are to secure an economic recovery with reasonable rapidity in relieving our people of the suffering consequent on the devastation of war, is that the country should be research-minded and realise that by research alone can we hope to make such an advance in the increase of productivity as to be able to secure for our people not only the maintenance of their existing standard of life but an ever-rising standard such as we all desire.

I note that the Committee appointed by the Lord President last week is to have power to enquire into the scope of the work of D.S.I.R.

May I most earnestly commend this suggestion to them for early consideration, in view of the urgency of the matter. If this proposal is outside their terms of reference, I trust they will be extended to include it or that a separate committee will be set up for the purpose of giving it consideration, so that as a nation we may be equipped to play our part in promoting international collaboration in the interests of peace and human progress.

Dr. P. Dunsheath, C.B.E.—Like Sir William Larke, I also would like to put forward views as an industrialist. There is one point which has appeared in these discussions to-day and will appear on a larger scale to-morrow, which might be referred to at the close of this meeting : that is, planning as it affects and is affected by human personality.

Professor Goodeve referred to an example in the type of industry with which he was associated in the Admiralty during the war, where it was necessary to secure the co-operation of the user. There we have an excellent example where human personality is the first and main factor in securing success.

Without securing support in an industrial concern on the production side the research worker will fail in the specific problem which he is endeavouring to solve. But not only the securing of co-operation on the user-research basis should be stressed : reference must also be made to planning as it affects the personality of the actual research workers concerned.

Professor Munro referred to the fact that during the war we had carried to a successful conclusion investigations that had been started before the war and had been based entirely on the interest in personal research. That has been done largely during the war, and even previously it had been fairly general in industry. Professor Tansley, in showing the importance of words and motives, divided scientific research, as we are all apt to do, into pure and applied ; but even they have the one common denominator, human personality.

Again, we have discussed the planning of research through teams, but whether research is carried out by an individual or a group of men, success still depends entirely on the human factor.

Planning, obviously, is an attempt to take the present and to construct the future from that present. It is not surprising that we should consider such a process reasonable but there are two types of growth between which we must distinguish in producing the future from the present. One of these types of growth is illustrated by the construction of a modern motor-car. We collect together on the assembly belt a chassis, the wheels, the body and a hundred accessories required to make the complete car. The failure of any one of these components to arrive at the right time and place wrecks the whole scheme, and yet when we have cranked up the engine and filled the tank, we have produced a living thing.

I do not look upon scientific research as typified by that nature of growth in the production of something living. The other distinct type of growth is the one suggested by a living plant. Those of us interested in gardening know the difficulties we may have to produce from the living seed the plants which ultimately give the yield we desire. As seeds are shy in this way, so the ideas which we hope to evolve by organisation, planning and research are similarly shy. What is the essential difference between these two processes ? In the one method of producing the living article we start with components which contain no life, while in the other we start with something which is an embryo, which contains life, and all we have to do is to provide it with conditions to bring that life to fruition.

It is common knowledge in industrial concerns that planned procedures are resented by the more intelligent workpeople, though girls and unskilled labourers willingly accept such direction. We have only to ask ourselves where the different ideas come from. They come from the more intelligent, and so without condemning planning —and I am entirely with Sir William Larke in what he said about *laissez-faire* being out-of-date— we must be careful in our planning so as to encourage the seed to grow rather than to do that which might prevent it coming through and giving us the results we require.

Because of these thoughts I am very anxious that we should not take too much notice of what is said far too frequently, that by following American methods and spending money in large schemes for planning research, we are going along the right lines. It is far better that we should consider the human side of the people producing the ideas, and if we do so I am quite sure that planning of research will produce results which will astonish the most optimistic.

Dr. J. R. Baker.—When people press for the central planning of scientific research, they are animated by the belief that certain distinguished committee-members can see the important gaps in scientific knowledge which are hidden—for some unexplained reason—from the mere investigator who works in the laboratory. It is my purpose to dispute this view.

Authority often works to the grave detriment of science. Hoppe-Seyler, for instance, the greatest authority on respiration in his time, delayed the discovery of cytochrome by thirty-nine years, through his contemptuous dismissal of the work of McMunn. That great physicist, Michelson, was incapable of glimpsing the future of physics. He thought that all the major discoveries had been made, and that it was only necessary to improve the accuracy of physical constants. The future of physics, in the words of his aphorism, lay " in the sixth place of decimals." He had not the faintest idea that the world was on the brink of the greatest developments that the subject has ever known—for the discoveries of Becquerel, the Curies, Röntgen, Planck and Einstein were just about to be made, to be followed not long afterwards by those of Rutherford and the other great students of atomic structure.

It is not simply that the great authorities in a subject fail to see the gaps in knowledge. Often no one working at a given subject can do so. The fresh view-point of someone working in another

field is required. This can be illustrated over and over again in science. For instance, the grand principle of the conservation of energy was not discovered by a physicist at all, but by a physiologist investigating the effect of a tropical climate on human blood. J. R. Mayer put forward his theory of the conservation of energy in 1842, and got a rough figure for the mechanical equivalent of heat before Joule, and well before Helmholz. Osmosis, again, was not first studied by a physicist. It was a botanist, Pfeffer, who first made a thorough investigation of the properties of semi-permeable membranes. That was in 1877, and in the same year another very distinguished botanist, de Vries, saw the connection between osmotic pressure and molecular weight. It was these two botanists who paved the way for the work of van't Hoff ten years later. In the present century the same thing happened in connection with hydrogen ion concentration. A biochemist, Sörensen, was investigating enzymes and required a measure of acidity and alkalinity in his work. It was he who introduced the *p*H notation and the use of standard buffer solutions.

The view that the progress of scientific discovery is unpredictable is not held just by a few second-rate enthusiasts. It is held by many of the greatest scientists, and indeed by the greatest scientist of our times. I want to read to you the words of Albert Einstein, published only a few weeks ago. 'Can you imagine an organisation of scientists making the discoveries of Charles Darwin?' he asked. 'One can organise to apply a discovery already made, but not to make one. Only a free individual can make a discovery.'

Prof. E. W. Marchant.[1] — Although planning research with a definite objective may be possible and necessary in many cases, the most noteworthy of which, of course, has been the research into the manufacture of the atomic bomb, I think a great deal is to be said for fundamental research which is not completely planned. After all, research is a progressive occupation, and if the ends of research are known, the word research rather loses its significance. Many cases have come to the notice of anyone who has been occupied with research work, which illustrate this point. One of the most recent which has come to my notice has been an investigation undertaken in the Electrical Engineering Department at Liverpool, to study the dielectric strength of air and other insulating materials under high-frequency stresses. The result that was being aimed at was a purely scientific observation, which was of some theoretical interest, as it was anticipated that the dielectric strength of air at a frequency of the order of 100 Mc/s would be substantially higher than that at a frequency of 1 Mc/s. This apparatus was used to measure the dielectric strength of other substances, and in the course of this investigation it was observed that the materials tested heated up very rapidly. This led to a difficulty in making exact measurements of power factor near the points of break-down, and I remember remarking to the research student who was engaged on this investigation, that this arrangement might provide a method of heating some dielectrics, but that the arrangement would not be very efficient. This investigation, although planned for the observation of a purely scientific result, actually led to an observation of heating which subsequently was of great practical utility, and the research might well have been diverted to a study of the heating of dielectrics, had we known how useful this method would prove in actual practice. Although, therefore, the planning of research is no doubt advisable and necessary in certain directions, planned research in which the research is definitely leading to a definite objective may prove much less fruitful than research in which facility is given to follow up lines of work which are suggested by the results that have been observed in the original plan. I think, therefore, that the greatest possible freedom should be given to investigators who have the ability to carry on advanced investigations. Another example of the same kind was in the experiments made over thirty years ago in the Electrical Engineering Department of the University of Liverpool, by Mr. E. A. Watson on the dielectric strength of compressed air. Within the last few years these results have led to great practical developments. First, in compressed gas cables, and quite recently, in compressed gas condensers or capacitors and air blast circuit breakers, and compressed air instrument transformers. These are only two examples; one could give many others of researches undertaken for a purely scientific object which have led to developments far removed from the objects for which the original investigation was started.

ECONOMIC ASPECTS OF RESEARCH

SATURDAY, DECEMBER 8: MORNING SESSION

ADDRESS BY LIEUT.-COLONEL L. URWICK, O.B.E., M.C., M.A., CHAIRMAN OF THE SESSION

IN 1886 Mr. H. R. Towne, of the Yale and Towne Manufacturing Company, read a paper to the American Society of Mechanical Engineers entitled *The Engineer as an Economist*. His general thesis was that engineers had up to that time been too much absorbed in the technical details of their craft, and had paid too little attention to the economic framework within which that craft must necessarily be exercised. In the following year, 1887, Messrs. Emile Garcke and J. M. Fells published in London the first edition

[1] Communicated but not spoken.

of their *Factory Accounts*. One of the authors was an accountant and the other an engineer. They quoted on their title-page an observation by Dr. Johnson from his preface to Rolt's *Dictionary of Commerce* :

'The counting-house of an accomplished merchant is a school of method wherein the great science may be learned of ranging particulars under generals, of bringing the different parts of a transaction together, and of showing at one view a long series of dealing and exchange.'

Further, they printed as an appendix to their book Oberlin Smith's paper on *The Nomenclature of Machine Details* read to the A.S.M.E. in 1881 : it was one of the earliest examples of an analytical study of a problem of industrial organisation to appear in the United States : it was acknowledged by Frederick Winslow Taylor in the first edition of his *Shop Management* as one of the sources on which he had drawn in developing his theory of Scientific Management.

These details of forgotten contributions to technical proceedings, contributions which, technically speaking, have long been superseded, may seem unimportant. But they have a wider significance than the mere technical accomplishment which they register, a significance which has a direct bearing on the subject we are meeting to discuss to-day. The thesis that the engineer, the man trained in certain applied sciences, had both something to learn from and something to teach to the economist and the accountant and *vice versa*, appears to have occurred almost simultaneously to small groups of individuals on both sides of the Atlantic.

The fact that there were some engineers and accountants prepared to think along those lines was in itself remarkable in view of the arrangements which at that time dominated factory organisation. The 'technical' departments conducted by engineers were sharply divided from the 'commercial' side, which was the concern of accountants. And while the engineer's training gave him an undue advantage in the construction of frontier fortifications, the accountant's background supplied a compensating acquaintance with the perhaps more important art of camouflage. The protagonists were evenly matched and, more often than not, the battle became one of attrition. That an accountant and an engineer should write a book together was indeed a mating of Montagu and Capulet.

Despite the traditional coolness of the families, represented in this instance by the professional institutions, such unions are sometimes very fruitful. This one certainly was. For the meeting of engineers and accountants, their endeavour to understand each other's outlook and to assimilate the two branches of knowledge to the more effective control of manufacturing enterprises regarded as a single unit, was one of the most powerful of the factors making for the development of a scientific attitude towards problems of industrial management. Both in the U.S.A. and in Great Britain this co-ordination of two previously independent techniques was immensely fertile and led in part to a wholly new outlook towards the overall problem of conducting industry efficiently.

Is it too much to suggest that by putting on its agenda to-day 'The Economic Aspects of Research' the British Association has in mind the possibility of an even wider integration? Up to 1880 the engineers whose inventions had been the main factor which made the Industrial Revolution possible had tended to remain aloof from the problems of social organisation created by that very development. They lived, as it were, in their own ivory tower of technical competence and interest.

In the nineteen-forties the position occupied at the earlier date by the engineers had been taken over in large measure by workers in the pure and applied physical sciences. The disciplines dealing with material have been advanced to a stage at which the technical content of practically every industrial process is fundamentally dependent on research in one or more of the applied sciences. Yet, in a very real sense, the scientific worker lives apart from industry. He produces knowledge, information, which others use or abuse. He regards it as no part of his responsibility, those who employ him do not regard it as part of their responsibility, to integrate his thought with their decisions as to the organisation of economic life or to be dissatisfied where methods of scientific thinking are not applied to and scientific knowledge is inadequate to provide answers to the problems which face them.

There is thus a tendency, which is coming to be recognised more and more widely as the root of the troubles which face our civilisation, to advance knowledge of and to provide resources for research into the physical sciences where immediate economic advantages can be clearly demonstrated, which is putting our whole apparatus of knowledge, and consequently our economic and social systems, out of balance. It is useless to put a high-powered automobile into the hands of 'babes in the darkling wood.'

A very wise American industrialist, Mr. H. S. Dennison, founded much of his theory

of business organisation on this principle of balance. He wrote :

'A special task of continuous reorganisation is to see that the units of the organisation are kept in balance—that there is a reasonable relative apportionment of strength among its departments. It is literally true that one arm of any service may at any moment be too good, so that something in the nature of a salient may grow. Any provision, even one for self-preservation may become too much for the rest of the organisation and defeat its own purposes. The classic example of over-preparedness is the armoured dinosaur who was so well protected that he finally failed to earn a living.' [1] What is true of industrial organisation is also true of social organisation and of the structure of knowledge which underlies it. If, as is increasingly accepted, it is true that our scientific knowledge is out of balance, that there is an inadequate appreciation of the importance of applying scientific methods of thinking to administrative, political, social and politico-economic problems, that we are under-equipped to use the equipment which the physical sciences have placed within our grasp, there is only one cure.

As engineers and accountants, technical and commercial men, began to come together more than fifty years ago on the problem of the overall management of the single industrial enterprise, so scientific workers on the one hand and administrators and financiers on the other, must come closer together to-day on the overall government of the societies which the sciences dealing with things have so profoundly revolutionised.

It is useless for either party to stand on the sidelines and say that it is the other little boy who has a dirty nose. It is a common problem which can only be solved by the integration of many different outlooks and many different skills. The *will* to collaborate should be shared by all. It is the special contribution of the scientist, and may I include in that category the genuine student of Scientific Industrial Management, that he has the intellectual training which should clarify his mind on the *way* to collaborate. There is thus a special responsibility laid upon him to take the initiative. He cannot and should not blame the lay administrator for lack of the knowledge and training which the scientist has the good fortune to possess—only for failure to realise the measure of his ignorance.

That is why I particularly welcome the inclusion of this subject in the proceedings of the British Association to-day. It is a sign that the scientist is taking the initiative.

[1] *Organisation Engineering*, p. 185.

Prof. P. Sargant Florence

1. THERE have recently been many conferences and reports on planning the relations of pure or 'fundamental' scientific research and applied research. One of the many problems discussed was the allocation of these two stages in the transmutation of knowledge into commodities as between universities, research institutions and industrial organisations.

2. On this occasion I want to point to further stages in this transmutation of ideas into products, particularly the economic stages (hitherto much neglected in the deliberations of scientists) following upon development and laboratory production. These later stages of preproduction and getting into mass production in a factory [2] are economic in that costs must be balanced against returns. This balancing is not necessarily only in terms of money, but might be in terms of manpower. Industry leaves these stages largely (at least in this country) to rule of thumb, tradition, and hand-to-mouth devices. There is usually no idea of research at universities or elsewhere.

In contrast to this practice my present thesis is that to the economic stages a scientific research can be applied similarly to the research in the natural sciences ; and that such research could similarly be developed at universities, in scientific institutions and in industry itself.

3. Setting up a factory in which to make available to the community as economically as possible the new commodities deriving from scientific research means bringing together physical equipment and an organisation of human beings in an effective whole. It involves engineering knowledge about the properties of matter such as strength of structures and efficiency of machines. But this is not enough. The equipment and machines must be co-ordinated and kept going on output at fullest possible capacity.

Knowledge is also involved of the properties of man such as his incentives to work, the etiology of fatigue and unrest, the distribution of abilities among the population and methods for testing for ability. The scientific study of these properties is at present shared between special disciplines such as psychology, economics and other social sciences without, however, sufficient liaison for the practical problems of the factory set-up. Liaison between these disciplines should be achieved at universities having departments of engineering, of commerce, of social sciences ; and also at meetings of the British Association, since out of its thirteen sections six deal with 'pure' natural sciences, two (engineering and agricul-

[2] Dr. A. P. M. (now Sir Arthur) Fleming, in a paper before the Industrial Co-ordination Committee of the British Association in 1931 distinguishes five stages : (1) Fundamental research. (2) Industrial research to 'test the possibilities of practical industrial application and maybe the economic value of the idea in comparison with any competitive production which it is designed to replace.' (3) Semi-scale manufacture 'which will enable all manufacturing difficulties likely to be encountered in full-scale manufacture to be overcome. (4) Selection and training of workers to undertake the commercial production and the problems of finance. (5) The design and installation of the requisite productive facilities and the building up of the manufacturing organisation.

ture) with applied natural sciences and five (geography, economics, anthropology, psychology and educational science) partly or wholly with human institutions. By instituting joint meetings between sections for the discussion of common problems, the British Association has been a pioneer in seeking a liaison between the human sciences and the natural sciences that might solve engineering problems.

4. The practical problems connected with setting up and running a factory are listed in the first column of the accompanying chart (p. 313). They fall logically into four consecutive groups :—

(*a*) Choosing a place to set up in and the determining of some range of size for the plant and the firm (which may own several plants). The solution of such problems and the related problems of the scale on which each type of product is to be made and the degree of mechanisation, involves economic considerations. These considerations include transport costs, the position of the market, the extent of the demand and the relative costs of a unit of output to quantity produced—what the economists call the law of increasing returns—leading to the possible discovery of the optimum economic lot, that is the best quantity to make at any given time.

(*b*) Problems of production engineering internal to the factory once it is built. Here the need for liaison between natural and human sciences is most clear. Once the size and place of the factory is determined it must be laid out in departments to assemble or process goods with minimum cost of internal transport. Within the departments the work to be done must be broken down into separate parts and processes (i.e., 'jobs') with a skill rating on which wage rates will depend and with normal times and motions assigned. Very often this is called time and motion study. They are problems which may be linked with 'industrial psychology.' This work of lay-out and job analysis to obtain maximum economy is often assigned to a special factory planning department. As a check on efficiency, quality as well as quantity control must be organised.

(*c*) Problems relating predominantly to the single human individual such as selecting the right workers, providing incentive (including wage systems) and avoiding fatigue. These three are perhaps the leading practical problems in industrial psychology. The general field of the human factor will presumably be discussed in the next Session.

(*d*) Problems, predominantly social, of business administration and industrial relations including coping with group traditions and patterns of behaviour and attitudes among the workers.

5. How far in these four groups of problems can research worthy of the name scientific and worthy of university teaching be said to have been carried? By the phrase scientific research I refer to mood and methods of work : to work which aims at objective truth in the indicative mood; and starts with sufficiently comprehensive observed data, uses fairly exact measures (e.g. statistical frequency distributions), and isolates or cancels out, by averaging or by experimental analysis, extraneous factors before proceeding to generalisations and interpretations.

The answer is that work in the scientific *mood* has been done in all four groups of problem—some leading examples are given in the second column of the accompanying chart. And all those put down, I think, do obey the scientific mood. But work adopting scientific methods is published only in two groups.

In Group C, industrial psychology, a great deal of statistical work has been done, beginning with the British Association Committee on Fatigue from the Economic Standpoint. It was appointed in 1913 and I had the honour of being Secretary of that Committee at a very early age. I had not taken a degree, and I think the economists, seeing an undergraduate, thought they could put it on to me. The study of fatigue was regarded as rather silly, but it did develop during the war of 1914–18. An official committee was appointed by Mr. Lloyd George, the Health of Munition Workers Committee, which did a magnificent job of research. This work unfortunately has not been extended but has been merely summarised in this war. In America a similar investigation on the effect of long hours on efficiency was carried out by the U.S. Public Health Service in 1917 to 1920.

There has also been a good deal done by the Industrial Health Research Board on the scientific study of incentives and by the National Institute of Industrial Psychology and the Birmingham Education Committee in guiding children by psychological tests. That is all work which has adopted scientific methods, especially of a statistical nature. So we can say that a good deal of research has been done in Group C by scientific methods.

In Group A it has been my endeavour to introduce scientific methods in the study of the size of plant and the location of plant, made possible by the censuses of production in 1930 and 1935. Those censuses allow us, indeed, to pursue scientific methods, mainly statistical, on the relation between location of industry and the size of plant.[1]

In Group B (engineering) scientific methods are being used by expert consultants and within big business organisations, but are not generally published for industry at large to profit by ; nor are they being taught at universities—at any rate, British universities.

Most of the problems of Group D (Management) are still mainly in the non-statistical isolated observation (almost the merely anecdotal) stage. Talks on the subjects tell you what wonderful things are happening in that particular department. I will leave it at that. There is not much scientific method based on general observation. At the least, however, a body of knowledge is being accumulated which should be pooled for the benefit of all producers and which when organised

[1] See my forthcoming *Investment, Location and Size of Plant* (Cambridge University Press), based on statistics of the Census of Production.

sufficiently to generalise and interpret deserves teaching at the university level. This teaching is in fact general practice in the United States, and if England is to prosper in a competitive world the training of many more 'cadets' for future business leadership must be undertaken at British Universities and possibly, too, in special institutions, and industry itself. At the British Association meeting in 1931 one session was entirely devoted to preparation for management and I had the honour on that occasion to expound the methods of teaching commerce at Birmingham. The University of Birmingham was, in fact, the first to start a Faculty of Commerce where teaching of this sort took place. Certainly the British Association has been alive to problems of preparation for management.

6. If the aim of productive industries is to raise standards of living by supplying ever-increasing types of goods at low prices, it is precisely the problems of production engineering and production management that must be tackled in a scientific mood and by scientific methods. Mass-production in large organisations makes it economically necessary to plan design and method of production and to tool up carefully beforehand, to check up on efficiency and economy in performance and to study the representation (e.g. through trade unions) and the basic background of attitudes of large groups, the better to administer the masses of workers employed. The control of such mass-production requires both ability of a high order and learning; a body of scientific knowledge and training in scientific methods, possibly at university level.

Before the days of large mass-producing factories the abilities required of a manager were compared by Ruskin to those required 'in the subordinate officers of a ship, or of a regiment, or in the curate of a country parish.' Adam Smith thought the employers' task merely one of 'inspection and direction' capable of being 'committed to some principal clerk,' and John Stuart Mill opined that to exercise control of the operations of industry with efficiency 'if the concern is large and complicated, requires great assiduity and often no ordinary skill' (*Political Economy* II, XV, § 1). Sir William Ashley, indeed, comments in his *Business Economics* (I, § 2) that economists had for a long time a pretty poor opinion of the ability required in business. Many of them are still somewhat obsessed in their reasoning by the classical model of an owner-manager entrepreneur. That is, the man who works on such a small scale that he can provide his own capital. Opinion generally does not envisage the salaried general manager of a joint-stock company with scientific knowledge at hand and knowing how to act on the advice of special experts. The actual position often lies between two stools. Many British firms possess neither the *artful* urge of the entrepreneur paid by profit, nor yet the scientific frame of mind of the expertly advised, trained and knowledgeable salaried manager with something more than mere exposure to experience to his credit. When I advocate training in management I am met by the argument that what we want is more experience. No one asserts that the graduate, aged 21, is capable of being manager of a joint-stock company. But, requiring experience, the choice is between experience without training and experience with training. Experience is exposure and being knocked about by the buffets of fate. You may be a well-weathered rock, but still a rock, if you are without training to make use of your experience. Sir Horace Wilson pointed out in a paper before the British Association in 1931, "Many observers think that the weak parts of British industrial structure lie not so much in its plant or technical efficiency as in its organisation,' and (in the same paragraph) 'available experience suggests that the technique necessary for the management of a very large concern differs materially from that now generally employed in industry. We cannot rely on the fact that there are many men available who have shown that they can manage medium or small businesses with great efficiency; such men may be quite unsuccessful with a much larger business.' I might point to the social importance of large-scale management brought forward by Mr. Burnham. His book, which has caused a great deal of stir in managerial circles, is significantly called the managerial revolution. He thinks the future lies not with the proletariat and not with the capitalist but with managers, and that the manager is going to be the key man of the future.

If there still is an art in large-scale production engineering and management, it clearly is (or should be) the experimental, analytical art of a profession like medicine, based on certain fundamental sciences. The recent cotton textile mission to the U.S.A., headed by Sir Frank Platt, cited (as an example of the 'analytical outlook' of American management) 'the experiments which are frequently made to establish the most economic balance between machine and labour efficiency. Thus, different machine speeds and numbers of spindles (or units) per operative may be tried to ascertain this balance. The manner in which operations are performed by operatives is also closely studied and analysed, and in this respect time-motion investigations are widely used.'

The Platt mission to America also found that it was customary for the manager to have as his assistant a young man who is a specialist, for example in engineering, and who has undergone a degree-course training at one of the American universities. The chief value of a university course is often not the technical knowledge imbibed but the scientific spirit of experiment and analysis that should there be cultivated.

7. Production engineering in its various branches indicated in the chart is largely based on the laws of mechanics and the natural sciences generally, but those trained *solely* in engineering at the universities cannot be said to have been pioneers. It was left to more practical men like Frederick Taylor to try to found a scientific management and he soon discovered the importance of the human factor. It is now recognised that production engineering also deals partly, and production management almost wholly, with the human factor.

The art of production management, like production engineering, must be experimental and analytical, based on social sciences such as social psychology, anthropology, economics and politi-

cal science. The political science underlying the art of management is brought out clearly in the works of Fayol and Urwick[1] dealing with the analysis and allocation of management functions. As I have pointed out on several occasions,[2] there are in large industrial organisations the same sorts of work-sharing and rule-sharing relations and the same problems of manning the organisation as in the government of the State. Research into rule-sharing would be likely to yield particularly important results on such problems as (1) how many subordinates one man can efficiently supervise and (2) what powers of rule cannot be delegated without losing sight of the end in view—powers to be reserved in a core of ultimate control. The comparative efficiency of alternative solutions in industry could be investigated—if research of this sort were sufficiently recognised—by standard cost accounting and budgetary control. But here England lags behind German and American practice. May I support very warmly what our Chairman said about the importance of the relation between cost accounts and management?

Industrial relations as a possible field for scientific enquiry on which to base production management

[1] E.g. *The Elements of Administration* (Pitman & Sons), and papers to the British Association.

[2] Florence, *The Statistical Method in Economics and Political Science*, 1929, esp. Chap. XIX. *The Method and Content of Political Science*, Aristotelian Society, February, 1934.

CHART

Contribution of Human Sciences to Production Problem

Leading Problems Grouped	*Content and Outstanding Pioneer Work*
A. *Industrial Economics*	
SIZE OF FIRM AND PLANT	Economics of Large Scale Finance and Marketing. Limits to Large Scale Management.
LOCATION OF PLANT	Economics of Localisation (External Economies). Transport Costs of Materials and of Products to Market. *Weber's Standortstheorie.*
SCALE OF PRODUCTION	Classical Economists' Laws of Increasing and Diminishing Return. The Economic " Lot " : degree of mass-production.
B. *Production Engineering*	
LAY OUT	Analysis of technical " routing " requirements.
JOB ANALYSIS	(*a*) Breakdown of manufacturing process into jobs. (*b*) Rating the skill of the job.
TIME AND MOTION STUDY	*Frederick Taylor, Scientific Management.* The Expert Consultant.
QUALITY CONTROL	Technical Statistics.
C. *Industrial Psychology*	
FATIGUE	British Association Committee on Fatigue, 1913–1917. Health of Munition Workers Committee, 1915–18. U.S. Public Health Bulletin 106, 1921.
INCENTIVES	Industrial Health Research Board, especially Reports 77, 82.
SELECTION	National Institute of Industrial Psychology. Birmingham Education Committee on Vocational Guidance.
D. *Production Management*	
BUSINESS ADMINISTRATION	(*a*) Applied Political Science : *Urwick, Fayol.* (*b*) Budgetary Control : Standard Costings.
INDUSTRIAL RELATIONS	*Sidney Webb—Industrial Democracy.* *Follett—Dynamic Administration.*
GROUPING AND ATTITUDES OF RANK AND FILE	*Marie Jahoda* at Marienthal. *Mayo, Whitehead & Roethlisberger* at the Hawthorne Plant. Social Psychology, Social Anthropology.

policy was, however, first opened up in England. Indeed, so powerful was the pioneering of Mr. and Mrs. Sidney Webb in their *History of Trade Unions* and *Industrial Democracy* at the end of the last century that English writers have been content to quarry from those monuments rather than from fresh ground. Pioneer researches in present day facts of industrial democracy have now passed to America: e.g. the work of Slichter and Dickinson on Trade Union policy, and of Mary Follet on Industrial Relations generally.

The social anthropology and social psychology underlying management can be exemplified in Whitehead's *The Industrial Worker*, Roethlisberger & Dickson's *Management and the Worker* and indeed in all the investigations of Elton Mayo and his assistants at the Hawthorne Works. He is an Australian who holds a professorship at Harvard and worked with his assistants for five or six years in a large electrical engineering works. There they discovered a strict code of conduct on what is done and what is not done reminiscent of the aboriginal tribes or of a public school, and which opened up important fresh fields for scientific research. They found groups of men and women had four rules which to break would have been taboo. You must not do too much work. If you did you were supposed to be 'rate-busting.' Secondly, you must not 'chisel,' i.e., do too little. I did not find that rule in a public school. But the first rule was there all right. We did not call it 'rate-busting,' but 'swotting.'

Then you must not tell tales out of school. We had that all right. In America it was called squealing and we called it sneaking.

Finally, you must not be superior. We called it swanking. The American factory also had that. If you were an inspector you must not behave as an inspector. Taking things all round these rules were far more important than making large wages, though not to do much too work means economic loss. To understand a factory, even in America, you must have some knowledge of social anthropology, because of these definite taboos and codes of conduct which are strictly observed.

To sum up: past discussions have omitted to deal with the later stages of the application of research in the natural sciences to industrial production, the stage of getting into economic factory production. If products are to be priced low enough to stimulate export and generally to increase standards of living, these later stages must use research in economics and the social as well as the natural sciences. Methods and results of this research should form part of the teaching at universities, designed to lay the foundation stone for future leadership in industry and commerce. Research applied to production on a large scale must tackle four groups of problems, Industrial Economics, Production Engineering, Industrial Psychology, and Production Management. Some research is taking place in industrial economics and psychology, but published 'pooled' research (and teaching at university level) in production engineering and management lags behind, particularly in this country. Successful factory operation is more than just designing machines and equipment regardless of economic cost of production or even cost of maintenance.

The matter is vital. Increased exports and improved standards of living at home depend on research in economics and the social sciences combining with research in production engineering and the natural sciences to further national efficiency in getting into the large scale production which we require.

Mr. F. E. Smith

THE subject of this particular discussion—'The Economic Aspects of Research'—inevitably suggests a balance sheet, comparing effort expended with benefits gained. Any accurate and comprehensive comparison of this kind is clearly impossible, but an attempt will be made to draw attention to some general points in this connection and to suggest where improvements may be made in the efficiency of applying the results of research to the benefit of the community.

As a result of the war and the wider appreciation of the value of scientific effort which now exists, there is some tendency, at least in the popular mind, to invest research with magical properties and to treat it almost with the looseness of the Black Art itself. Much has been written recently which suggests that if a firm or an industry will but put its hand in its pocket and spend the necessary money on research it will thereby open to itself a source of untold wealth. It is quite certain that if it does not spend it will not get the results, but the converse is not necessarily true. There is also a leaning in many quarters relatively to over-stress research while paying insufficient attention to the subsequent stages of design, production, distribution, etc., which are equally important for efficient overall working.

I do not know if there is a satisfactory and widely accepted definition of research, but I venture to frame my remarks on the assumption that 'research is the process of gaining knowledge in a systematic manner by the study of phenomena, or by the examination and correlation of existing data.' On this basis research can cover an extremely wide range of endeavour in any field of human activity. For instance, the definition would apply to a systematic study of the effectiveness of a particular form of advertising, to the effect of profit-sharing on output under given conditions, or to fundamental research on atomic structure. It would exclude such a case as the routine analysis required to check an industrial process operation, whereas it would admit the investigation of such a process in order to improve its efficiency.

It is clear that those industries or professions which have made the biggest relative effort on research have, in general, been the most successful and, at the same time, the most stable. This is no doubt due in considerable measure to the direct technical results of such research but also to the infusion of the critical and scientific outlook into all branches of any organisation which becomes research minded.

Looking first at manufacturing industries, and considering the scale of physical research as affecting production, we find extreme variations between different types of industry. Concrete figures capable of comparative analysis are seldom published, but it is clear that in the backward industries research is usually negligible. In these

cases an expenditure of one-tenth of one per cent. of turnover has been suggested as a desirable but at present unattainable bogey, small though the figure is.

On the other hand, some industries which are highly organised and which rest on a scientific basis may spend on research as much as 2 per cent. or even more of their turnover ; in America this figure is being exceeded. In this country, for example, the largest unit of the chemical industry has an annual research expenditure of some £2,000,000. This does not include the £500,000 which is spent on process and analytical control, but only research as defined above. It is important to note that research on such a scale is carried out as a regular routine matter, not in the hope of making vast profits from any single invention but spread over the whole field covered by the industry.

It is convenient to divide industrial research into two main categories which may be termed Maintenance Research and New Products Research respectively.

Maintenance Research is research directed towards maintaining the competitive position of the firm in its established products. It covers improvements to processes leading to decreased costs of production. It also investigates new uses for the firm's existing products and provides technical service to customers by research on special problems. Its problems are usually of short range and the results can be assessed in a comparatively short time, say five years. Work on small systematic improvements to processes should therefore be charged to the processes, and if over five years or so the costs of production show a downward trend not accounted for by a fall in the price of raw materials and labour, the research expenditure is justified. The value of research on the use of products is less easy to assess but it is possible to do it by close liaison between the research and sales side of the organisation.

It is more difficult to assess the value of New Products Research, firstly because it takes much longer to get results, secondly because it has a larger proportion of failures, and thirdly because it is tied up with the long-term expansion policy of the firm. In a competitive world research is obviously worth while only if the ultimate results justify the cost. The governing factors vary from one industry to another, but in any particular case it is possible to arrive at a figure to guide the annual investment in research. It will be usual to capitalise the research and development charges of any new process, but it must be remembered that there should be also a real, if intangible, asset in the general knowledge applicable in other directions which results from undertaking research of this nature.

Among producing but non-manufacturing industries, coal-mining, with its related problem of distribution, gives a clear example of the difficulties which arise when research and scientific method have been largely neglected on both the technical and human sides. What a difference might have been effected in this vital industry if 1 per cent. of its turnover had been spent on research and scientific development for the past fifty years. At present rates this would yield some £4,000,000 per annum ; even one-tenth of this sum would surely have produced most valuable results and would have saved the community at least a proportion of its present difficulties.

As a concrete example of what can be achieved in a similar field, I would quote the actual case of a mineral mine where a levy of approximately 4 per cent. has been made on the value of each ton raised since the shafts were sunk. In this case the proceeds were applied not only to cover research and technical investigation but also to carry the overall cost of mechanising and developing the underground operations generally. It may be added that great attention was paid to the labour side as regards working conditions and to ensure that all parties shared financially in the progress made. That the investment was sound is shown by the fact that for comparable output and wage levels the cost per ton of raising the mineral fell by 15 per cent. and the output per man rose by 90 per cent. over a period of eight years. At the same time there was a steady improvement in the confidence and general outlook of the men.

It is true that this case refers to a relatively new mine and to conditions which are easier than in coal mining. This, however, does not prevent it serving as an example of what may be achieved by the continuous and forceful application of scientific method and technical development.

In British agriculture a great improvement has been effected during the war years. This has not been achieved by any increase of man-power, but by the application of knowledge gained by research, by the wider utilisation of machinery and by better organisation. Although the research effort on agriculture is not large in comparison with the financial turnover, it has been operative for a long period and has the benefit of direct contact with the production side at all stages. A good example of the technical interdependence of different industries, a subject about which much could be said, is provided by the benefits the farmer receives from research in the chemical industry in the way of fertilisers, selective weed killers, pest control, etc. Similarly, the chemical industry is in turn dependent on the efficient and up-to-date operations of the coal mining, engineering, metallurgical and instrument industries, to mention only a few.

The moral of this brief survey is clearly that research on a proper scale is vital for efficient working. It can only be economic, however, in so far as it is followed up by the technological and organisational development which it makes possible. It is in the *application* of new knowledge and ideas that this country frequently seems to lag, although we have been and are outstanding in fundamental research. It would appear worth while, then, to enquire what are the underlying reasons for this failure to obtain full benefits of our work in pure science. The following points appear pertinent :—

(*a*) Fundamental research has usually been carried out in universities or in scientific institutions which have had little direct interest in applying the results, or contact with those who might do so.

(*b*) The industries which might have taken up and applied basic knowledge either did not

exist in an organised form in this country, or did not possess staff with the scientific knowledge to appreciate the possibilities and the managerial ability to follow them up.

(*c*) As industrial processes become more complicated and more highly specialised it is often impossible to achieve any real measure of efficiency except by working on a very major scale. The large production units which are frequently necessary in this connection must in turn be based on a wide potential market. The relatively small population of this country is thus an inherent disadvantage.

(*d*) The fact that we were the pioneers in the industrial field can be, and frequently has been, a positive drawback as leading to reliance on existing plant, on methods of production and distribution and ways of thought which have not kept pace with the latest developments.

The war has shown what remarkable results can be achieved by united effort and has indicated some of the ways in which peace-time working can be improved. In particular, great advances in applied science have been made because scientists from the universities and other research institutions have had to work in direct contact with industry and the Services. It is very desirable that such a movement should not hold back work on the fundamental side, but it does indicate the need for movement of staff so that there is automatic interchange of knowledge and ideas right through the chain from pure research at the one end to production and use at the other.

The most urgent need is to ensure that fresh knowledge, whether arising from fundamental or objective research, is followed up and applied promptly and effectively. For this it is essential that industry should have the proper staff, that there should be a satisfactory system for the diffusion of information and that there should be good organisation and incentives. I shall only venture to touch on the first two of these requirements.

Industry must carry, in addition to its research staffs, a sufficiency of men who have had the education and training necessary to give them a broad fundamental knowledge and an all-round appreciation of research and development, of production and of user requirements in their respective fields. These are the key men who have frequently been lacking in industry as well as in peace-time Government establishments.

Experience has shown that such leaders can be produced without undue difficulty under a proper system of selection and training. The majority will be university graduates, but suitable men will come up from the ranks of the drawing-office or from laboratory assistants, etc., if the organisation is sound. As part of their training it is essential that they should be given the maximum of responsibility at all stages and that they should be moved round to obtain experience of all sides of the work which they may ultimately control. In general, responsibility cannot be given too young and the better the man the more frequent movement should be, especially during his early years.

I will illustrate this point in the field of mechanical engineering, but a similar argument is, I believe, generally applicable. In this case the key man is the 'design engineer.' It should be his function to marry together the possibilities thrown up by research, the potentialities of production and the real requirements of the user. It is at the design stage and at that stage only that these three angles, and they are often conflicting angles, can be properly combined to give the best overall result. This is not a job which can be carried by ordinary draughtsmen although it is often left to them to do the best they can, and it is certainly not one for the man having only research or theoretical training. On the other hand, if it is undertaken by the man who is primarily production-minded the result will usually be that he will follow well-known technique and will tend to resist any change which modifies existing production methods and equipment.

At the present time there are too few men of the required type in industry and they have mostly arrived by chance or exceptional personal effort, and not by the conscious planning of their training and functions on the part of the management. There are a small number of firms in this country who have appreciated the value of scientific design, but before the war far too many British firms were content to take their designs in whole or in part from America or the Continent. It is a matter of life and death to us that we should not sell our birthright in this way. By all means let us learn from others but let us ensure that this is a two-way process, and that we sell more than we buy; that on balance we lead and do not follow.

I have referred above to the importance of diffusing knowledge and this is a matter requiring the urgent attention of scientific institutions, of industry and of Government alike. With the vast and ever growing flood of technical and scientific work it will be necessary, and certainly economic, to take positive steps to organise the collection, storage and dissemination of the resulting information. We must place this knowledge at the elbow of every scientific and technical worker; we must not attempt to force it in unlimited measure into brains which have not changed appreciably in capacity since the first advent of scientific thought. If this were done universities and schools would concentrate on teaching their pupils how to think and how to use effectively the knowledge which should be available for all.

Something has already been accomplished by scientific societies, by research associations and by industry in sorting available information, but only on a small scale and without general co-ordination. Very little has been done to teach people to carry out their work in the full light of existing knowledge. The Americans appear to be conscious of this need and have taken some steps to fill it in certain directions as by the production of the Engineering Index. It is pertinent to ask how many firms in this country use the Index, covering 50,000 items per annum, and how many British engineers have ever seen or even heard of it?

It has been said, and it is a stimulating thought, that theoretically 'the whole of knowledge is

available for everyone to use.' Here is an opportunity for the scientific organisers to show their mettle and for the universities and industry to play their part in training men to make full use of the mighty tree of knowledge which is growing under the stimulus of science.

The above remarks have dealt mainly with the economics of research as affecting the material life of the community. I cannot finish, however, without touching on the need for applying research and scientific method to a more difficult but even more important field.

Whatever may be the shortcomings of physical science and of its application to production, it is increasingly clear that technical development has reached a point where it is out of balance with man's managerial ability in the fields of economics, sociology and political development. If the world's present ills are largely due to this unbalanced condition, the solution demands more research and better application of scientific principles on the economic and sociological side and not less in the field of physical science.

Is it not possible that the glitter of discovery and adventure, offered by the physical sciences during the past forty or fifty years, has attracted an undue proportion of the world's best brains? If this is so, there lies a clear duty on all those who guide the young, to fire their imagination with the great benefits to be secured for the human race by a similar keenness and enthusiasm applied to research on the humanistic side. As with the physical sciences, the fruits of this research have to be worked out and applied by men with the requisite scientific training combined with practical experience, if it is to be fully effective.

Nature has ordained that there shall be no standing still; the organism—individual or collective—is going up or going down. Without scientific and successful management in the world's affairs all may be lost; with it what splendid visions open up for the future of mankind as the economic results of research, properly applied in every field of human activity.

Prof. M. L. E. Oliphant, F.R.S.

I SPEAK as a pure scientist who has been jolted out of his ivory tower of pure research by experiences both before and during the war. Before the war I became increasingly aware of the inability of British industry to provide pure science with the equipment that it needed if it was to go ahead in parallel with advance in other countries. In fact, industry which was asked to provide new and much-needed equipment was not interested. The equipment was needed in small quantities, perhaps difficult to produce, and did not promise any immediate economic market, so it was necessary to go abroad even for the apparatus with which to carry out fundamental research in this country. In Cambridge, I remember, we had to go to Holland. This state of affairs enphasised the great contrast between the outlook of the pure scientist and the outlook of the industrialist or the industrial scientist, and I will have something more to say about that in a moment.

If I may give an example of a pure scientist visiting America and driving a car in which he had those sealed beam headlamps which never get dirty and never fog up, returning to this country and asking the industrialists why they did not do the same for British cars. He was told by the industrial research director that they had looked into the matter and it was not economic. I cannot believe that was so. It was one of those examples of the job being done at present in some other way and of vested interests preferring that it should continue so; and this attitude has been confirmed during the war years.

Also on visiting the United States one became convinced, as a pure scientist, what an invidious comparison it was possible to make between the two countries, with regard particularly to the later stages of the application of science to industry, a factor which has been emphasised by Mr. F. E. Smith. It was also shown by the difference between the two countries in the attitude towards science and the scientists, of the administration, the top control of industry. Pure science in the United Kingdom has been notable throughout the years for consistently throwing up in succession genius of the highest magnitude. From Newton to Rutherford we have a stream of names which stand out in the world of science and mean a tremendous amount nowadays in applied science; and there is a strange thing about the work of these pure scientists in the past in Great Britain. They emerged, despite the fact that the total resources applied to pure science in this country have always been small, and the total number of people engaged in it has always been rather pathetically insignificant. Perhaps as a matter of fact we can regard, together with the tradition of great writing, the ability to throw up great scientists as one of the greatest assets which this country possesses; but we cannot say the same of the ability to make use economically of the results obtained by those men.

There is also little evidence in the lives of those great scientists that they took the attitude which has grown up very recently in British science and, indeed, in science all over the world, that draws a line of demarcation between the scientist in his laboratory, pursuing science for its own sake, and the rest of the world outside milling round in order to make a living.

Scientists in the past were involved in the economics of their own country, concerned often with the application of the work they themselves did. From Newton to Kelvin and later, they have played a great part directly in their own lifetime in the scientific advance of the economy of this country.

This attitude which has grown up is therefore not traditional, as is often claimed. There is no doubt about it, the first duty of the pure scientist is to work in the laboratory; but he also has an equally strong duty to perform to see that his results are carried further into the economy of the country, into both industry and politics, because politics themselves create the conditions of the economy in which the scientist has to work.

Applied science in the United Kingdom, however, stands in a very different category from applied science in America, Germany, and the U.S.S.R. The position in Great Britain is

anything but satisfactory, and I think the whole crux of the matter is the difference in Great Britain of the financial structure of our industry as compared with that of other countries. In England we have too many sleeping partners and moribund directors whose only interest in their company in the Midlands or North of England, is to totter up to a directors' meeting once or twice a year, a meeting which is held in London usually a great way from the industry. There it is insisted that a proposal by the technical manager that he should spend £500,000 for research and new equipment is unnecessary in the face of the overriding necessity to keep the dividends up, and to ensure that the market value of the shares is as advantageous as possible. The director's attitude is not applied to long-range thinking about the industry. As Professor Florence emphasised the economic factor in the end determines success or failure ; but the man who takes that point of view alone does not look ahead at all. That is to my mind wrong, and there is a great lack of the spirit of adventure in industry and applied research : one must have that spirit if one looks far enough ahead to ensure the success of the future.

In England we have a great stranglehold of American and other foreign financial controls over our own industries, and some of us know a great deal of what has happened in recent years in acquiring financial interests in some of our more important and progressive industries. Unfortunately, it always happens, when that takes place, that the centre of the research department is moved to America or to some other country, and is no longer here, as it is judged unnecessary to maintain a research organisation in both places. They want the company here only in order to produce here, so as to overcome fiscal barriers. This is a slippery slope down which we may rapidly travel, because it means as soon as this state of affairs becomes at all prominent, dollars become more and more desirable, and hence there arises a growing tendency to sell out and get dollars and invest in industry on the other side. There is little interest in risking anything under these conditions. One of our big firms of plastic manufacturers was recently acquired by one of the larger American chemical combines. The managing director, or president as he would be called, told me they had examined the future policies of their company in this country, and had decided there was little hope for the future because of the large cost in this country, first of transport, and secondly of electrical power, as compared with America, and that their company intend using England only as a means of getting behind certain barriers. He was quite frank about the matter.

There is something seriously wrong with our methods of dealing with a firm in financial difficulties—a firm of engineers, for instance, with a great international reputation, which, when things got wrong, was put into the hands, not of an industrialist who knows technically the industry and the job, but of a chartered accountant whose business it is to see that money is not spent, and consequently it is not spent on essentials. And this applies to the research side. That is the first thing pruned by the accountant, because it does not seem to contribute to the immediate profits of the particular industry.

Another problem of management in Great Britain is that I think we lack very much the actual scientific point of view. We certainly lack the scientific man in management. We lack also application of science to the many problems of industry outside the present research which goes on in the laboratories.

In this connection I would like to take issue with the previous speaker on one small point, much as I agree with practically everything he said. It is his contention that we should take the research worker in pure science and let him follow through, into applied science, the things on which he had been working in the field of pure science, the discoveries to which he had contributed. I think in this country that would kill pure science, because the conditions of applied science are what they are. This does not apply universally. There are some firms in which conditions are different, but if you approach a man who has worked for some time on the applied side of science and ask him to do something novel, his immediate reaction now is like that of the directors and managers. It cannot be done, it is not economic ; and that point of view is forced upon him by policies of finance and management higher up.

Dr. Conant, the President of Harvard, has emphasised some of the qualities necessary to ensure success in research, and his words were quoted in the House of Commons the other day. He said, in a letter to the *New York Times*: 'There is only one proved method of assisting the advancement of science : picking men of genius, backing them heavily and leaving them to direct themselves.' Then he went on to say about applied science : 'There is only one proved method of getting results in applied science: picking men of genius, backing them heavily and keeping their aim on the target chosen.' I would commend that very strongly to your attention—the fact that we are only going to get results by picking the man and backing him, whether for pure or for applied science.

It is necessary, to my mind, to preserve some balance in progress, and to keep in step all along. Improvements in applied science and in business management and economics, and particularly improvements in one's moral outlook on the world should go hand in hand. I think all advance in any one of these directions is rather more like a quantum advance than a clean smooth classical advance. Advance always takes place by jumps, and sometimes very big jumps, and they tend to keep us out of balance. And if I may make a particular comment, I think that is a rather healthy state of affairs, provided the disturbance of balance is not too big, because it is only by driving people a little hard and making advances in one particular direction, say in the direction of pure physical science, by an economic advance or by making one big jump in one of these spheres, that enthusiasm and the will to advance in those other spheres is engendered. The discovery of the release of nuclear energy is a case in point which may have more to do with the advancement of man's moral outlook in the world than any amount of moral teaching.

Some years ago Lord Rutherford in the House of Lords made a great plea for the setting up of what he called a pre-vision committee which was to look ahead and try to see from knowledge of recent advances what sort of things were likely to become of economic importance in the near future. He pointed out the ability of the scientist, not only in physical science, but in all branches, to assist in trying to make that map of the immediate future which could be used as a guide to our administrators. I would emphasise that that is as necessary in State enterprise as in private industry, if not more so. It is no good having the scientist in State or industry unless some notice is taken of his views and some effort made to incorporate his knowledge and effort into the knowledge which forms the framework of any policy which may be put forward, either by industry or by Government.

Those who are foremost in urging caution about the future of atomic energy; those who tell us it is going to be a long time before it may be applied, and that there are grave difficulties in the way, and that it is necessary to explore every avenue before we take steps in the dark and so on—it is they who plead for that caution who are in a position to ensure that is exercised, because so often they hold the purse strings, and they are high up in the councils of the nation, and control policies in more senses than one. I would urge that it is impossible for us to direct our scientific effort in this country if it is to be founded always on a policy of caution, engendered by people who have, in fact, a controlling power. There is too much lip-service to science at the moment and too little effort to get things done. Discussions take place in industry and Government, but there is little action.

One word about universities. I think it is essential to try to keep this research spirit which has guided British science through the centuries much more firmly in our applied science, and is is essential, as the previous speaker said, to remove from university training a great deal of the vocational training which is now given in applied science. It is impossible for universities to train men nowadays in practical production engineering. What they can do is to build up in a man the proper background of pure science, which forms the whole basis of the science of engineering production, and send him out into the world, into industry, imbued with the spirit of science and research and development. Let him get his training in production methods and in the machinery of industry in industry as it exists to-day.

It is necessary, of course, before that can be done, for industry to take a more sympathetic point of view, and not to suppose, when they admit a man into industry, that he will immediately be able to improve the ordinary production of the industry. After leaving the university he has to be trained as an engineering or an industrial man. In the university he can only lay the foundations, and until we get back to the recognition of that fact and begin to lay the foundations, and not to try to teach him to be an engineer in the real sense, we shall not provide this country with either the engineers or managers which we need for the future.

Discussion

Dr. P. O. Rosin.[1]—This morning's conference deals with the 'Economic Aspects of Research.' In fixing the agenda in these terms, I cannot help feeling that not sufficient attention has been given to a fundamental principle of research. This principle requires that, whenever we are faced with a problem, we have first to define it; and the definition of a problem in research is not just a linguistic process carried out in a few minutes or hours, but a painstaking mental process of elimination, based on acquiring and analysing all existing knowledge of the particular subject and its related fields, a process which may take many weeks or even months. Carried out in such a way, the defining of a problem is already half of its solution, and, incidentally, the safest way to apply research in an economic manner.

In fixing to-day's agenda, the process of definition seems to have been lacking, for we have been presented with three different interpretations which, though all of them highly interesting, may leave a confusing, or at least unsatisfactory, impression. Let us first agree on what is meant by the economic aspects of research.

In doing so I would first make an observation which has so far been lacking in many discussions on post-war research. The war has shown what research, and in particular organised and teamwork research, can do. But the achievements of research during the war have been obtained with a complete disregard of our present-day conception of economy. The currency in which the return from research was assessed was not money but human lives and the winning of battles. This has led to a distortion in the minds of many people about what research could contribute—and in what time—towards the solving of our post-war problems.

Let us be frank: we have learnt what science can achieve in war, when money does not count, but we have still to define what research can do in a post-war period where it has to fit into an economic and legislatory system in which its economic aspects will ultimately be measured by the monetary balance sheet of a particular enterprise, or, if you include the communal services, of the country as a whole. Let me give a few examples. Many scientific war achievements, haloed with the glamour of research, are now being abandoned because they are thought to be uneconomic. Fido, though based on much scientific research and already half-completed at London's new airport, Heathrow, is being scrapped on economic grounds. Pluto has been dismantled equally for lack of money. And the same applies to the results of many other wartime researches; and it may be said in passing, but with deep regret, that no organisation seems to exist to collect and publish the complete scientific account of war research.

Our task to-day is therefore to define how research can best be fitted into our existing economic conditions. I said previously that we have been presented with three different interpretations. To explain this, let me substitute for a

[1] The Chairman introduced Dr. Rosin as a chemical engineer, nationalised in Britain after escape from the Nazi régime in Germany.

moment management for economics, for it is the administration of a company which is responsible for its economic success. Three combinations between research and management are possible : (1) the management of research, (2) research on scientific management, (3) the relation between research and management, or the attitude of the administrator towards the research worker, and *vice versa*.

We have heard to-day interesting views on all three combinations. Mr. Smith has largely dealt with the management of research, Professor Florence with research in exploiting research, and Professor Oliphant, as well as the Chairman, with the direction of research and with the qualifications required to create an understanding between research worker and administrator. In my opinion this understanding between the two, this partnership in mind between the scientist and administrator, is the essential prerequisite for the economic application and development of research in our industry. But to-day they often speak a different language. Neither their way of thinking and expression nor their outlook is conducive to an understanding. The administrator sometimes underrates or overrates the potential of research, but almost always underrates the time and expenditure necessary for solving a problem ; and the research worker, engrossed in his problem, may have a distorted perspective of the general situation of the business. And let us not overlook one important human fact. Only in very rare cases do the administrator and research worker meet on an equal basis. In most cases it is a meeting between an employer and an employee, be it the research worker in industry who has to report to his director, or the outside scientific adviser employed by a company. In my opinion wherever research is playing an integral part in the life of a business, the partnership of minds between the administrator and research worker should also be a partnership in chairs—the director of research should have a seat on the Board, so that he may be informed of the general situation and may speak on equal terms. This practice has already been adopted in many places in America, and in some instances in this country.

When we now come to the economic application of research, we best consider it as a form of mental energy which, like the mechanical energy of engines, the chemical energy of reactions and the physical energy of labour, must be put to the most efficient economic application. Here we should distinguish, as Mr. Smith has already done, two fields of applied research, improvement research and development research. Improvement research is largely what Mr. Smith has called maintenance research, but is often also 'trouble shooting.' Development research is the nursing of a new produce or process through all its phases. At the present moment, and again largely due to the scientific achievements of the war, the imagination of most administrators is caught by the prospects of development research, of which wonders are expected, but it is my conviction that in our present situation of conversion, 90 per cent. of our industrial scientific potential should be turned to improvement research. The efficiencies of many of our producing and distributing industries are deplorably low, the quality of many goods should be raised without increasing their prices ; in every branch of industry and agriculture there are almost unlimited possibilities for improvement by applying research to existing processes—and here lies, in my opinion, the safest way for the economic application of research. Incidentally, the understanding between administrator and research worker will be least difficult in this field. And the improvement researcher of to-day will be the development researcher of to-morrow.

There is one aspect of the economics of development research which I was surprised not to find mentioned in any of to-day's papers, namely the relation to our patent system. I do not propose to deal with it, but wish to emphasise that the patent aspect is, in my experience, the most powerful factor influencing the economics of research.

So much is general, and I now wish to make a few comments on Professor Florence's inspiring paper, carrying this new subject a little further, even though that may appear premature at a time when most of his ideas have hardly been adopted by industry. He recommends general investigation applicable to industry as a whole, but we must also distinguish between the basic characteristics common to all industries and the specific features pertaining to a certain group of industries. The basic characteristics depend largely on the economic structure of a country, while the specific features differ widely among various branches such as the chemical industries and the engineering trade. Is it not possible to separate the basic from the specific features by establishing, besides the well-known facts and requirements common to all branches of our industry, as a result of economic research, the typical features of management and cost accounting resulting from the structure of a particular industry? Based on such a research, the optimum system of planning and controlling production, of wage and time fixing, of loading machines or production departments, of material control and cost accounting, could be worked out as proposed standards for a particular group in industry, and could be applied in any research carried out for the development of new processes and plant.

We then come to the most difficult point in Professor Florence's paper : the co-ordination of process and production research. Where should it begin? In my opinion at the pilot plant, this being the platform on which the final layout should be determined. This means that the economic research worker, recommended by Professor Florence, should take part in the pilot experiments, and that the pilot installation should be modified not only according to the requirements of process, plant and product, but also according to the four groups listed by Professor Florence. For each test run, a combination of all factors, technical and economic, must be derived pointing to, and ultimately determining, the optimum layout and operation of the production plant.

However, it is already difficult to strike the optimum compromise between technical factors alone, and the task becomes incomparably more difficult by adding numerous human and economic factors. It may well be that special systems for

analysing the results of numerous test runs will have to be developed, and I have in mind the modern statistics machinery, such as punch card systems, which allow of the quick and variegated analysing and summarising of a great wealth of data.

The recommendations of Professor Florence will introduce economic considerations already at the pilot plant stage, and this is essential since, in my opinion, at this stage financial backing by the government is mostly needed.

I have seen many promising inventions and developments frustrated by lack of money for adequate pilot plants, or by the neglect of the economic aspects, and if research grants be given for this purpose, their economic use should be safeguarded. Production is a compromise between the properties of material, forces, the human factor and economics. If the optimum compromise could be predetermined by integrating the various researches and weighting their results right from the early development, a great step forward would be initiated in the economic application of research.

Prof. J. D. Bernal, F.R.S.—I do not find it as difficult as the last speaker to reconcile the various views we have heard this morning, but I feel strongly that he has added that note of caution that Professor Oliphant particularly wanted to avoid. Yet I think there are occasions when caution can be positive.

I must say, in looking over the whole field, that in this conference, in spite of violent differences of opinion, we have the materials out of which to make one of those quantum jumps which Professor Oliphant mentioned. It is clear that experience of the war and the troubles of the present time, such as the anxieties over atomic energy, will produce enough momentum to fuse these different aspects and to raise us to a new level of integration. I think the two key words here are integration of these different techniques, and the infiltration of scientific methods. There is a distinction between them. The infiltration process consists in extending the range of scientific mood and scientific method. The scientific mood is directed to the discovery and solving of problems without self-interest in a narrow sense. It is very difficult to acquire, either in Government administration or in industry. The scientific mood enters more and more when there is a general polarisation and direction of national effort.

Mr. Morrison said that it was much easier to do things during the war because we all wanted to do the same thing, and that enabled us to get the scientific mood into the whole of military operations and war industry. I do not feel that that is really so dangerous as Dr. Rosin seemed to think—that it was not economic and would not pay. The point is that there is a different standard of economic demand, and there is, of course, the question whether we cannot change over our objective—what we call economy—to suit our needs rather than to be absolutely confined by these systems of accountancy which he mentioned, or by the patent system. If it turns out that the patent system is the chief source and obstruction in the application of science to industry, the answer is to change the patent system. It is not a fact of nature, like many of the obstructive properties of materials with which we have to deal.

There is a very close analogy in Professor Sargant Florence's analysis between the two human institutional organisations of war and industry. His big grouping—industrial economics, production engineering, industrial psychology and production management—corresponds to those we have all experienced in military operations and which have been well recognised for a long time. Strategy is the same as industrial economics in the sense that both deal with what you are trying to do, and what is done is by means of tactics—processes in the factory, production engineering. Then there is industrial psychology and the personnel side, which correspond to the selection and establishment branch of the Services. These have developed enormously in the war. I am surprised, however, that in that group Professor Florence did not mention training, because training is really the next step that comes after selection. Perhaps the great psychological discovery of the previous war was fatigue, but in this war training methods were of enormous value, and we have the need for it in every industry. We know we can fit all kinds of people for all kinds of operations by scientifically selecting and training them. We have, for example, in the industry a bricklayer, who took four or five years to become one. He was not trained to become a bricklayer, but like the experienced manager he has had experience, and after a certain length of time he becomes a bricklayer or manager. We now know we can carry out that process, I do not say in three days, but in six months, and we can enormously add to our potential by scientific training.

Finally, and I think most important of all the groups, is production management which is what we have called in military affairs, command or staff work. One of the other things the war has taught us, is that we can easily be scientific about command. What was one of the worst parts of the army was becoming one of its best. There is an enormous amount to be learned. I want to stress that this directed effort called military operations is not unlike the economic operations in peace, and, I think, can be carried out with the same drive without any loss of economy.

We can solve the economic question by concentrating and unifying. That is where integration comes in. The particular difficulties of a particular firm can be remedied and reinforcements can be sent to it; and we must not say that we cannot advance because our own forces are not large enough and we cannot call for support. We shall be able to get over this difference between restrictive economy and progressive scientific advance.

The Chairman.—Professor Bernal has said that the patent system is not a fact of nature, like many of the obstructive qualities of materials with which we have to deal; but my feeling in listening to the discussion has been that inevitably it has come back to another fact of nature, namely, the obstructive and refractory qualities of man; and it seems to me that if we are to get the integration and infiltration of thinking we have got to make a scientific analysis.

First of all, following Dr. Rosin, we have to define our objective, and secondly, we have to make a scientific analysis of the obstructions which have emerged as a result of the various experiences which have been read before us this morning. For instance Professor Florence urges that we must have a social anthropology. I agree, and recognise how far we are yet away from the scientific method which will give us a true social anthropology.

Mr. Smith drew attention to the national fashion for empiricism or trial and error. We shall not be scientifically minded until every administrator remembers his own errors and the trials they are to other people.

Then Mr. Smith spoke of the interchange of persons to different occupations so as to broaden their minds. That is another obstacle—the occupational groove. This is not confined to the Civil Service, though rather prominent in that particular environment.

Lastly, there is lack of training and the way to search for knowledge. Of course, that is another example of a type of human obstruction, departmentalism, because every department of knowledge, just as every department of Whitehall, goes driving towards its own publication, its own activity, without reference to the general policy of enquiry, of which its own activity is only a small contribution. It is another example of the misconception mentioned by Professor Oliphant, the false line of demarcation between pure and applied science—another example of departmentalism.

Another point which he mentioned was the economic tendency to say 'it cannot be done.' Surely that is a product of the conventional thinking which divides time into periods of twelve months for financial purposes. Surely we can have some scientific study of the way to break down that sort of conventional thinking—the experience of the war should have done so.

The problem before us, then, is to recognise first the objective of this morning's discussion—to examine how to use and develop the scientific mood and scientific method so that the knowledge which we already possess, or which we are in process of acquiring, may fructify in welfare for this nation, and for all nations. The means is infiltration and integration of that knowledge. The obstacles are obstacles in thinking.

THE HUMAN FACTOR

Saturday, December 8 : Afternoon Session

Address by Dr. Raymond Priestley, Chairman of the Session

This afternoon we tackle the question of the human factor in research. Here perhaps we have the limiting factor as regards both quality and quantity of research. The British people have no monopoly of inventiveness and research-mindedness, yet, I believe, we have no cause for pessimism, for history has shown that we produce, generation after generation, a higher than average number of individuals with a marked flair for invention and research.

As the Vice-Chancellor of a University I naturally look upon this problem from a particular point of view, that of the discovery and education of research personnel. It seems to me that, broadly considered, the problem has three elements. We need the maximum possible number of exceptionally gifted individuals, most of whom will work in isolation on particular problems, but some of whom are capable of inspiring and leading research teams or of attracting disciples and so founding schools. We must find, in addition, and educate appropriately, a very large number of men and women capable of pursuing, under direction, faithfully, doggedly and with intellectual integrity, investigations that form part of the mosaic that, through the genius of the team leader, will eventually become a pattern rendering intelligible a whole new field of knowledge, or, alternatively, are capable of discovering paths into the unknown about the borderlands of science, most of which they know will lead to nothing, but one or two of which may open up new worth-while fields. These men may have their researches suggested to them, but they must pursue them with pertinacity, intelligence and zeal. They must have a thorough knowledge of their subject, and of cognate subjects, and they must be well trained in research discipline and experimental technique. They must be able to persevere and, even more important, they must know when to stop. They are the rank and file of research workers : the men for whose making the degree of Doctor of Philosophy and the whole system of university research under supervision were devised. From among them will come the leaders who will pass relatively rapidly through their ranks to form my first class, but most of them will become the regimental officers of the research system or, if they are in the universities, pass over more and more to the teaching side. Among them will be found much of the salt of the university earth.

Lastly we have the vast body of technical assistants, laboratory attendants, workshop technicians and so forth, without whom

research in experimental science could not be carried on. In our universities at any rate these men and women have been the Cinderellas of research. There have never been enough of them and they have seldom been systematically trained. They form a reservoir of potential research workers that has never been sufficiently exploited. If education and promotion had been easy for them there would have been more Gowland Hopkinses in the past. We need to see to it that in the future ' mute inglorious Miltons ' are unknown at any rate to science.

What do we need to do to see that the nation makes the most of its resources in these three fields ? Selection of the first class is a comparatively easy matter. They select themselves. You cannot keep the first-class research worker down. But you can see that he gets up more quickly and you can see that he comes up in the right place. In my own opinion—perhaps I am biased—our great need here is to spread these men and women, among whom are the great masters and team leaders of the future, the inventors and the catalysts of research, as widely as possible. At the university stage we must break the monopoly that Oxford and Cambridge hold to-day and have two dozen instead of two major centres of learning and research, each with internationally recognised schools in several fields. Beyond the university stage we must attract and even persuade a larger proportion of our leading lights into research institutes, the Government scientific services, and industrial research laboratories. Wherever they are they must be given a free hand and fed with all they need—not necessarily, I fear, with all they think they want, though with these men it is better to err on the generous side, for ' you never know.'

As regards the second class of research worker—the main body—the chief needs, I think, are three. We need more post-graduate studentships to encourage promising men to try out their hands and brains at supervised research, and these studentships must provide a decent living to enable the recipient to concentrate on his work, though he should do a little teaching for the good both of his soul and his future career. We in the universities also need more research fellowships to strengthen our schools and teams with men with research experience and mature minds. The fellowship system needs to be flexible so that man-power can be moved where progress is most needed, potentialities are greatest or where the great leader has appeared. We need freer circulation between university laboratories and research organisations in government and industry, and franker and more frequent discussion and pooling of results. Finally, we need far more adequate provision of my third class, skilled assistance of all sorts, assistance made more zealous and more valuable by better conditions of service and more systematic education and better prospects of promotion. To-day this is one of the universities' weaker spots.

I should like to finish on a note that is, I know, more debatable and may be thought to be somewhat beside the point. There is, I think, urgent need for the scientist's education to be more closely related to the facts of social and political life. It is true that, in spite of their highly specialised education, our greatest scientists have a real grasp of the social significance of science. I doubt if this is sufficiently true of the rank and file. I should like to see imported into the education of the scientist at a fairly late stage some element which would force him to think about and study the history of the world in which he lives. It would help him to apply to the whole of life the qualities which make for success in his own speciality. When I hear the suggestion that all that is needed to put the world right is to give the scientist his rightful place in government, I have certain reservations. Too many of my scientific friends fail in this respect. They apply to their own subject a very efficient experimental technique. In pursuing it they impose on themselves a severe intellectual discipline. In consequence, when they make pronouncements upon it they are 99½ per cent. right. They are too liable to transfer this sense of infallibility to other walks of life without employing either the technique or the discipline, sometimes with disastrous effects.

Sir A. P. M. Fleming, C.B.E.

In research, as in every enterprise, the human factor is all-important. Money, equipment and facilities are all of relatively small significance if there is a lack of first-class suitably trained personnel. In considering the human factor in relation to research and industrial planning, it is necessary first of all to consider, from the industrial point of view, just what functions have to be dealt with by the research personnel.

The place of research in relation to industry can be placed on a number of different levels, but for the purposes of this discussion I would like to consider that the function of research in industry is to achieve the utmost efficiency in the industrial transformation of raw materials into finished products. This function embraces not only the long-term research of an academic character which provides new scientific discoveries and new knowledge, but also that which is concerned with the application of this knowledge to specific industrial problems. Further, it involves the personnel of a more technical than necessarily

scientific character who are concerned with what, in industry, may be termed ' development work,' i.e. the important bridge whereby the results of the research laboratory can be translated into such a form as to enable conventional production to proceed on a commercial scale. The range of personnel, moreover, includes the psychologist and physiologist who are concerned with the selection and training of industrial workers so as to utilise human energies most efficiently. It will be seen that at one end of this scale of personnel there is the scientist concerned with academic research, and, at the other, the person who has received basic technical training in applied science appropriate to the industry in which he finds himself, and in this respect his training is not dissimilar from that of those who find technical employment in other branches of industry such as design, production, technical salesmanship, etc.

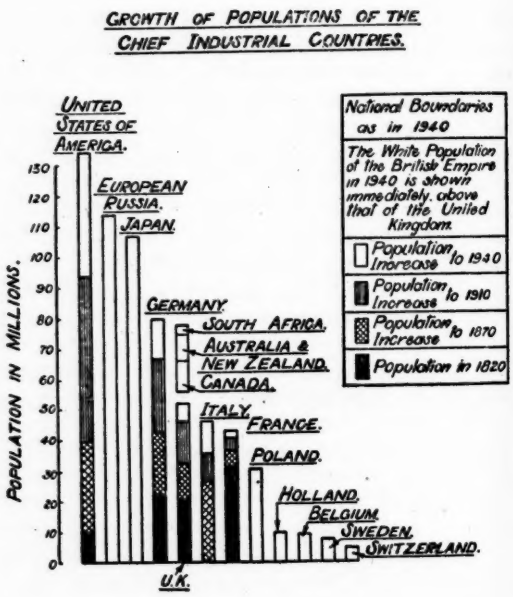
Other than by a few industrial concerns, research in industry was unknown in this country earlier than about twenty-five years ago. Since then there has been an ever-increasing demand for the whole range of scientific and technically trained personnel I have mentioned. Not only have an increasing number of firms established research organisations, but research associations have also required to be staffed to a continually increasing extent, Government laboratories have made a considerable demand on such personnel, all industries have tended to augment the size of their technical staffs, universities have established research schools, and now, after the war there is no doubt that the fighting forces and Government research establishments will need much larger and better trained staffs than in pre-war days. The result of all this is that the demand for personnel of the kind under consideration has increased enormously. The supply must come almost entirely from the secondary schools, directly or by way of the universities. In the former case this involves a period of part-time technical study before a suitable standard of knowledge is acquired. Throughout this period, however, the population from which this personnel is drawn has not increased correspondingly.

Seeing that in the future we shall be engaged in ever-increasing competition internationally for world markets, and knowing the importance of the overseas markets to this country, it is worth while to examine this question of population, since this will provide us with the principal means of competition. In the diagrams now shown, the growth of the populations of the chief industrial countries in the last 125 years is presented, and probable future trends are given in a table.

Many data are implicit in these diagrams ; and the following points are to be especially noted. *First*, if present trends continue the population of France, the United Kingdom and Germany will remain practically static (although the white population of the British Empire may increase somewhat) ; the population of the U.S.A., Italy and Poland will increase appreciably ; the population of Russia will increase considerably ; and what happens to Japan's population is perhaps unpredictable. *Second*, the white population of the British Empire is by no means negligible in comparison with the U.S.A. and Russian populations. *Third*, if China and India were included, the height of the diagram would have to be increased three times ! One of the major considerations of our planning should therefore be the raising of the educational and technological standard of the Empire's non-white populations.

The size of our population relative to that of other countries necessitates the use of all our personnel to the best possible advantage. This means a continual raising of the level of intelligence applied in industry, in which our material prosperity depends. By increasing in number and quality our research workers, ultimately the whole technical level throughout industry is raised.

The quality of our research personnel is of equal importance to its quantity. The quality depends on the efficiency and up-to-dateness of our educational system ; including elementary and secondary schools, universities and technical colleges. I will not go into this matter further, except to note that industry itself also has an important part to play in education. On the side of technology, and in the release of young workers for further education, industry is already doing a great deal ; but industrial firms must also be prepared to do their part in the training of research workers, and should not look upon the university product as a finished research tool.



From the foregoing it will be seen that, in view of the increasing demands for personnel of the type we are considering and the numbers available to us, we should draw to the greatest possible extent on Empire resources and develop to the utmost education and practical training, so as to ensure in quality what we may lack in quantity.

There are, however, other aspects of the human factor in this question of research in industrial planning. There is the management of industry to be taken into account. While there are notable exceptions where progressive industrialists are reaching out to apply science in business, to a large number ' research ' is simply a word,

and a possible means of securing a certain alleviation of taxation, as indicated in the last budget of the Coalition Government. We have to remember that this is a country of small industrial concerns, all, with the exception of a very small percentage, employing normally less than 1,000 people. A few large firms have their own research organisations. The smaller depend on research associations, and the crying need is to ensure that in every manufacturing concern there is an officer who can assimilate, interpret and apply, as it becomes available, the scientific knowledge appropriate to his concern's field of industry.

Apart from the management, however, the whole of the personnel in industry needs to have its interest in research quickened. It is understandable, for instance, that engineers, designers and production staff are reluctant to change from established practice and the use of materials, processes and tools already employed, because of the cost and dislocation which this involves, and it becomes a matter of fine judgment to decide when, in an economic sense, it is timely to effect the changes which research brings about. Here again it is the attitude of the human mind which counts, and it is important to ensure in all the personnel concerned such an acute interest in, and realisation of, the importance of new knowledge that the timing is correctly observed.

With regard to the rank and file of workers adaptability is important. Those who have had experience of translating what appears to be a relatively well-developed process in the research laboratories into the conventional atmosphere of a manufacturing organisation, know how often failure results from this apparent lack of adaptability. Hence the significance of a group of personnel concerned with development which will ensure bridging over this gap effectively.

It may not be out of place in considering the human factor, to draw some comparisons between the character of the work and the responsibilities of the workers in long-term academic research, and those relating to the personnel concerned with research of an industrial character. The former are concerned with the discovery of new knowledge, and this is all-important, and to this work there is attached a certain glamour. The industrial research worker, on the other hand, is concerned with tackling industrial problems for which he needs to know a good deal about the economics of the problem, the limitations to manufacturing processes and procedure, and something of industrial administration and markets. If he is concerned with the introduction of new tools, new processes or materials, the time arises when he has to back his judgment by taking considerable risks which may have far-reaching economic consequences, and this calls for a good deal of judgment and courage. Moreover, as distinct from war-time conditions, an endeavour must be made in times of peace to conduct the researches with the maximum efficiency and

POPULATION PROJECTIONS, 1940 – 1970
(IN THOUSANDS TO THREE SIGNIFICANT FIGURES)

NATIONAL BOUNDARIES AS IN 1937: FIGURES TAKEN FROM A LEAGUE OF NATIONS PUBLICATION, GENEVA, 1944.

	1940	1945	1950	1955	1960	1965	1970
UNITED KINGDOM AND EIRE	50,200	50,600	50,600	50,200	49,400	48,200	46,800
FRANCE	41,200	40,800	40,300	39,700	39,000	38,100	36,900
GERMANY	69,500	71,200	72,000	72,200	71,800	71,100	69,800
ITALY	44,200	45,700	47,000	48,100	48,900	49,500	49,500
POLAND	35,200	36,700	38,100	39,400	40,400	41,000	41,400
SPAIN	25,600	26,400	27,000	27,500	27,800	28,000	27,800
HOLLAND	8,840	9,230	9,550	9,780	9,950	10,000	10,000
BELGIUM	8,310	8,350	8,340	8,270	8,160	7,980	7,760
SWEDEN	6,330	6,380	6,370	6,310	6,210	6,050	5,840
SWITZERLAND	4,220	4,260	4,260	4,220	4,150	4,050	3,920
CZECHOSLOVAKIA	15,300	15,500	15,600	15,600	15,500	15,200	14,900
U.S.S.R. (EUROPEAN AND ASIATIC)	174,000	189,000	203,000	216,000	228,000	240,000	251,000

economy, because the money available must come from earnings which have to be shared between the demands of research, the need for replacement of tools and equipment and buildings, the setting up of some reserves and the payment at any rate of something to shareholders in order to ensure the supply of fresh capital when this is required for the expansion or continuity of the business. It would sometimes appear that the industrial worker does not receive as full recognition of his services as is justified.

The human factor also outcrops in the matter of public opinion. Interest has been aroused by the fact that during the war science has achieved many new and improved means of destruction, and there now appears to be some hope in the public mind that it can do something in the way of creation of things and conditions which may make for a better world. This idea needs developing in order to ensure a strong and healthy public opinion in the direction of encouraging the application of scientific research in all the services affecting the public, and this calls for well-designed propaganda and general education.

Mr. Alec Rodger

I WANT to speak briefly, and in general terms, about the contribution which I believe industrial psychologists can make to industrial reconstruction.

But first let me survey rapidly the development of their activities. In the early days of their work in this country—a quarter of a century ago—they were concerned mainly with investigations into the relationship between hours of work and productive efficiency. Later, they became involved in enquiries into methods of work and into accident causation. This brought them inevitably to the consideration of problems of personnel selection and vocational guidance. Next they became interested in methods of training industrial workers. They were led incidentally to studies of sickness absenteeism and of problems arising in the heating, lighting and ventilation of workplaces. And many of their investigations threw up problems connected with the design and lay-out of equipment. Nor has this been all. Enquiries into incentives and into management-worker relations have added further variety to their programme.

Now, the nature and width of their interests have stimulated criticism. Surely, it is said, many of these problems are not psychological. It is probably unnecessary for me, at a meeting of this kind, to consider this objection in detail, but I feel impelled to make one comment on it. No industrial psychologist would maintain that any of these problems is purely psychological. Most of them are for him practical problems which call for investigation from several viewpoints, one of which is his. He is too realistic—or should be too realistic—to expect ever to tackle an exclusively psychological enquiry. (As a psychiatrist, Dr. Ronald Hargreaves, has remarked: 'God doesn't usually distribute human problems under quite the same headings as university chairs'.)

There is then no reason to believe that the industrial psychologist's curiosity about these matters will diminish. His interests will continue to be wide. But this does not mean that he will in the future give each one the emphasis he has given it in the past. Representatives of other viewpoints have become sufficiently appreciative of his own to justify changes in the amount of attention he need devote to certain parts of his sphere of enquiry. For example, illumination engineers tend nowadays to be very expert in dealing with points which twenty years ago might not have been raised at all if no industrial psychologist had been available for consultation.

It is my belief that in the next decade or two industrial psychologists should concern themselves principally—though not exclusively—with four sets of problems: (1) vocational guidance and personnel selection; (2) methods of training; (3) the design and lay-out of equipment; (4) manager-worker relations. Their war-time duties, especially in the Service Departments, have added vastly to their experience in each of these fields, and the moment has come for the judicious application of that experience to civilian problems. I say 'judicious,' because obviously there can be little or no direct application of Service methods to civil life. There are, however, a number of important difficulties to be overcome, and I propose to occupy the rest of my time in enumerating them.

First, the 'public relations' of psychology in general are unsatisfactory. The psychologist—whether medical, educational or industrial—is regarded generally as being odd and rather frightening. He has a 'magic eye' and he is, of course, destructive. It was not Hilaire Belloc, but somebody else, who said of him:

'He takes the saint to pieces and labels all the parts.
He tabulates the secrets of loyal, loving hearts.
He probes our selfish passions and explains exactly why
The martyr went out singing, to suffer and to die.'

That, I think you will agree, is the psychologist's reputation in general.

The industrial psychologist is in some ways worse off than his medical psychological colleague, the psychiatrist, who derives a certain amount of protection from his membership of a powerful esoteric profession. Moreover, the industrial psychologist tends in practice—almost inevitably—to be regarded as a fault-finder. This fact was well illustrated by a brief telephone conversation between myself and someone in another section of the Government department which at present employs me. I asked, 'Is Mr. So-and-So in?' 'No,' came the answer, 'Who's speaking?' 'The Senior Psychologist,' I said. 'Oh!' replied the voice, and after a pause it went on, 'You're not very popular down here, are you?' 'I'm sorry to hear that,' I said, 'I wonder why?' 'Well,' came the response, 'Aren't you the people who are always finding something wrong?'

The second difficulty to be overcome is not unconnected with the first. Industrial psychology has in the past suffered from lack of official recognition. If it is going to be really useful, it must have the blessing and support of authority. It is of course our British way to allow enthusiasts to struggle along in penury for a lengthy trial

period. It may be a good way, but I suspect that we overdo it. Industrial psychology has had a hard life so far, and I suggest that it has made a sufficiently valuable contribution to the war effort to warrant its being regarded now as legitimate and even respectable.

The third difficulty arises from the plain fact that industrial psychologists are extremely scarce. Among the Fellows and Associates of the British Psychological Society, only about thirty are classified as industrial psychologists. If industrial psychology is to make a reasonably satisfactory contribution to industrial reconstruction, that number must be increased appreciably. We should, I think, aim at raising it to at least 120 during the next five years. Due for release from the Services within the next few months are dozens of men and women who have had useful experience of one aspect of industrial psychological work—personnel selection. I hope that it will prove possible for a number of them to go to a university—or go back to a university—for the purpose of studying psychology and making a career in it. But they must be reinforced by others with different experience. There is a considerable need in the industrial psychological sphere for men who have already graduated in physics or engineering. I hope that a good many of them are going to pay some attention to the possibility of work in applied psychology. Many would argue that even the target figure I have suggested—120—is really absurdly small. A current American psychological journal indicates that the U.S. Army Air Force still has about 200 commissioned aviation psychologists; and we know that two years ago there were 400 psychologists working for the U.S. Navy.

A fourth snag is to be found in the fact that training facilities are at present poor. I would like to see the National Institute of Industrial Psychology become a live centre of post-graduate training, linked closely with the universities, and particularly with the University of London. It should do sufficient 'practical work' to afford its trainees good opportunities for learning 'on the job,' but the emphasis should be on the training, mainly with the object of feeding industrial psychologists into appropriate consultant groups, both official and private. I suggest this, because I firmly believe that usually the industrial psychologist can make his contribution to the solution of a problem most effectively when he is working in collaboration with others. I need hardly add that industrial psychologists should not be concerned with the training of other industrial psychologists only. Dr. Aubrey Lewis has recently remarked that most of the psychiatric work which needs to be done in industry will have to be performed by people who are not themselves psychiatrists. The same is true of industrial psychological work. Suitable courses for personnel managers, employment officers, careers masters and others are needed almost as urgently as courses for industrial psychologists themselves.

My fifth and last difficulty is in some ways the most important of all. The industrial psychologist is inevitably an advocate and agent of scientific management. But, in this country at least, he has no taste for scientific management which is forcibly imposed upon the managed. This means that he feels in duty bound to win the support of both managements and workers. He cannot hope to do that adequately where there is fear of unemployment. This fear has always been, and will always be, the chief enemy of the industrial psychologist. He is concerned with the fostering of both efficiency and contentment at work, and neither efficiency nor contentment can be produced in groups of workers who are wondering whether this or that so-called 'improvement' is going to result in fewer jobs for fewer people. In other words, the industrial psychologist cannot be expected to make his maximum contribution to social and economic life until a 'full employment' policy is implemented and until we have a planned wage structure for the whole of industry.

And now to sum up: In my judgment, industrial psychologists can make a useful contribution to industrial reconstruction, particularly if they concentrate on four sets of problems—vocational guidance and personnel selection; methods of training; the design and lay-out of equipment; and management-worker relations. But they must themselves work hard to improve their acceptability and to win official support. Moreover, they must increase their numbers, so they must devote a good deal of their energies to the training of other industrial psychologists. Nor must they neglect the need for suitable courses for non-psychologists who deal with people before they enter industry, on the way to industry, and within industry. But even if they adopt these objectives, and even if they jump their hurdles well, their achievements will be disappointing unless they can pursue their investigations in a society which puts into practice a 'full employment' policy.

Let me say, in conclusion, that I feel very hopeful about the future. Twenty years ago, a famous psychologist, William McDougall, wrote: 'For me, psychology as it exists is no "nasty little science," but rather the beginnings of a science which is destined to be recognised as fundamental to all the human sciences. I carry this optimism very far. I anticipate that at no distant date, perhaps before the end of the century, even the University of Oxford may begin to take interest in the human mind and may set her hall-mark upon psychology by giving it a recognised place among her studies.' I understand that McDougall's Oxford prophecy is about to be fulfilled, though the century has not yet run half its course. Who knows what the other half may bring?

Mr. James T. Kendall

Education and Training of Research Workers

OTHER papers have been presented at this Conference, dealing with the relationship of scientific research to the various activities of the community, with the planning of research and with its economic aspects. In this session we are dealing with the Human Factor—with the way in which real human beings must fit into this rather abstract picture of planning and economics which has been painted for us in the previous sessions. Although the Human Factor is the last item on our agenda it is by no means the least important—because no matter how fine

and impressive are our plans for scientific research and industrial development, it must always be remembered that we poor mortals, with all our human faults and weaknesses, have to carry them out.

Sir Arthur Fleming has shown in his paper that our planning must be limited by the quantitative means at our disposal in regard to technical personnel. Our population is not infinitely large, and we must cut our plans to suit its actual size. From the qualitative point of view the picture is similar, and there is an obvious need to plan in the most efficient way possible our education and training of technical men and women.

In this paper I am proposing to deal particularly with this important question of education and training of scientific research workers. On this question I may perhaps be allowed to speak on behalf of the younger scientists ; and this point of view may be appropriate, since it is upon the idiosyncrasies and failings of the young embryonic scientists that many otherwise admirable schemes of education and training may fail. To borrow an industrial simile, it is a question of adapting one's manufacturing process to suit the peculiarities of the raw material.

The types of research worker in industry and university.—Before considering the process of manufacture by which we are going to arrive at our finished product—the perfect research worker—let us consider what are the real specifications both in industry and in universities, for such a product.

In the universities our model research worker has to perform two functions—pure research and teaching. In industry there are also two functions—pure research and applied research. It seems to be generally agreed that in universities the two functions of research and teaching can with advantage be combined, although there will of course be exceptions to this rule. In general, if the same man carries on both functions simultaneously they react favourably on each other. His pure research work is the better for his teaching activities, and his teaching is all the better for his contact with research. A proper balance between the two functions should as far as possible be left to the scientist himself. In most universities at present it is probable that more than the optimum proportion of time is spent on teaching activities—and it is difficult to see how this situation can be remedied unless university staffs are largely increased.

In industry it has generally been the practice to separate the two functions pure and applied research, that is, as far as the first function is carried on in industry at all. The two types of research may be carried out in the same laboratories, but not generally by the same persons. For example, pure research on the mechanical properties of metals at high temperatures may be carried on by one group of people ; and another group, perhaps situated in the same laboratory, may be carrying on applied research on blades for gas turbines. Both researches are interrelated, but it is impossible for the same people to carry on both activities at the same time. It is unfortunate that it is impossible to do this, because the separation of the two activities necessitates the provision of an efficient liaison between the two. In this country the gap existing between pure and applied research seems at times to be almost a yawning chasm, and in our post-war planning we must attempt to build a wide bridge across it. We must not, as in the past, lead the world in pure scientific research and lag behind in its application to industry.

One way of bridging the gap is by training our industrial personnel to think both ways—one may say fundamentally and practically—even when their actual work is concentrated on one or the other. For workers in applied research, there could be periodic advanced courses—provided by universities—dealing with the fundamental aspects of their work. For pure research workers, there could be what one might call 'industrial summer schools,' designed to help the pure scientist to realise what may be the practical consequences of his work. Schemes of intercommunication such as these have been of sporadic occurrence in the past. We must aim to make them a permanent and well-known feature of our academic and industrial post-war worlds.

Apart from these schemes for communication between the two worlds, one would also like to see some intermigration. For example, it is already quite usual for engineering and physics students to spend their vacations in industrial concerns. This arrangement could be carried to a higher level, and university scientists might, at intervals, spend a period of at least a few months in an industrial post. Conversely, the industrial scientist might spend occasionally a few months in a full-time academic post. The more the pure and applied scientists get mixed up in each other's affairs the less chance is there of an unbridgeable gulf between them. Manchester University now provides advanced courses in fundamental science for people working in industry, and it would be of great advantage if this provision were extended to all industrial centres. It has been of immense benefit to me as an applied scientist to attend such courses on fundamental research.

The basic psychology of research.—Having digressed for a moment on the two aspects of research—pure and applied—and the necessity for their close co-ordination, let us return to our specifications for a research scientist.

For research in pure science the basic requirements may be detailed as follows : firstly, a mind which has been trained to tackle problems by the so-called 'scientific method.' The 'scientific' approach to a problem involves the exercise of considerable scepticism, self-criticism and mental honesty. It may come naturally to some people, but for the most part I believe it has to be drilled into us. Secondly, a capacity for original thinking cannot be too strongly stressed. This, again, is sometimes a 'natural,' but can also be developed by suitable educational methods. A modern scientific education must unfortunately consist mainly of the digestion—or indigestion—of a great deal of factual knowledge ; but I do feel that a place should be found for some instruction in the art of thinking. I am not suggesting that a formal course in psychology should be given in schools, but the student should be given some idea of the kind of processes which go

on in the mind—as far as we know them. There is a definite routine required for efficient original thinking, and at present students are left to find this routine for themselves—with a consequent waste and inefficiency of effort on their part. Thirdly, I would place a highly specialised factual knowledge of a particular branch of science. Of course, a broad general knowledge of the whole field of science is required to begin with, but nowadays a very specialised knowledge of a particular sector is a necessity if a further advance is to be made. Fourthly, there is required a high standard in at least one of the modern experimental techniques—that is, mathematics or one of the manipulative techniques of physics, chemistry, engineering or biology. For pure theoreticians, mathematics by itself may be a sufficient technique. For the rest of us, some practical dexterity is usually required.

For research in applied science, exactly the same qualities are required with, in addition, a fifth—an instinct for thinking in a practical way, and a training in the principles of engineering practice and economics. The applied research worker requires a much more detailed knowledge of what may be summed up as technology than does the pure research worker. It is a pity if this requirement means that an applied scientist must receive a technical education rather than a scientific education, as he certainly ought to acquire as good a knowledge of the fundamental principles of science as does the pure scientist. The division into two branches—pure and applied science—should therefore only take place at the post-graduate stage. At that point the pure scientist can continue with specialised academic studies—leading eventually to his Doctorate of Science ; and provision might now be made for the applied scientist to continue with specialised research in industry—leading by various stages to his eventual Doctorate of Technology.

As a sixth and final requirement for our perfect research worker, it is becoming increasingly evident that all scientists will now have to take a greater interest in the social consequences and implications of their work. We can no longer work—as it were—in a vacuum, but must realise that other people, probably non-scientists, will be applying the results of our researches in unscientific and possibly suicidal ways. We must obviously intervene, and take an active interest—as scientists—in present-day social, political and economic questions. This implies that in addition to his specialised training, a scientist must have a broad general education designed to fit him to take an active interest in everyday affairs. I am saying, in effect, that early specialisation at school is to be avoided, and that later cultural studies are to be encouraged.

Early environment and education.—From the specifications for a research scientist which I have given, the best kind of education and training to give him can be derived by a simple process of induction. I do not propose therefore to deal with the question of school and university education in any detail—beyond noting that in many respects it does not at present seem to be a process which is ideally suited to the production of our perfect research scientist. However, I do not propose to enter now into a discussion of the evils of specialisation, excessive attention to examinations, and so on, important as these things are.

It may be of more interest to consider the state of affairs on either side of the period known as formal education. Very frequently the man who finds himself attracted to scientific research work has had in his early environment a lively and intellectual home life. It is difficult to assess the exact importance of this informal education, but it must be agreed that it is important. Now the number of such homes which contain comparatively intelligent and intellectual parents is fairly small in any country, but it is in direct relation to the standard of living and educational attainment of the mass of the population. Therefore, if we wish to increase substantially the number of first-class scientists in this country, we must aim at a general increase of the level of education and standard of living of the whole population. How many Faradays and Mendels have been lost owing to the seed falling on stony ground ?

Post-graduate training.—At the other end of his formal education our scientist receives a university degree, and he then expects to get down to the business of research itself. Or rather, the scientist of the pure type realises that he must spend a recognised apprenticeship of two or three years, working under the direction of a senior scientist, and that it is only after he has obtained his Ph.D. or similar degree, that he can expect to be able to do independent work. The applied scientist, on the other hand, sometimes thinks that his training is now finished, and that he can immediately be of great usefulness in an industrial position. If he does hold this view, he is quickly undeceived, and in fact a post-graduate apprenticeship of two or three years is just as essential in industry as it is in universities. It seems a pity to me that this training period cannot be recognised as it is in universities where they give a Ph.D. degree. The necessity for further training sometimes goes unrecognised not only by the scientist himself, but also by industry. It is, however, very important that industrial concerns should realise that university graduates in science —or for that matter even doctors of philosophy— are not capable of carrying out applied industrial research without some further training, which can only be supplied by industry itself and cannot be supplied by the universities. There are indications that industrial concerns in this country are beginning to realise this, and many of them now provide training schemes for university graduates —although these schemes may not be of a very formal character. The firm with which I am associated has for many years provided a two-year apprenticeship course for engineering graduates, and has recently extended this to include physicists, chemists and metallurgists.

Conclusion.—In conclusion, then, I should like to stress that the two most important considerations—from the standpoint of the Human Factor —with regard to scientific research and industrial planning, are first the education and training of our research personnel to the highest possible level, both in quality and quantity, and second the filling in of the gulf which seems to exist in this country between pure and applied research scientists.

Discussion

Prof. J. D. Bernal, F.R.S.—I would like to say something about the subject at this last, and I think most important, part of the conference. The importance of the human factor really underlies all the different sessions. It enters in a very big way, however, into science, because I think a great deal of the difficulties and arguments, and a great deal of the strong feelings that were aroused on this subject of the planning of science arise from a very real difference between scientific and other activities.

It is not absolutely peculiar to scientific activities. It really applies to all activities which can be distinguished in a sense by the word ' creative,' without quibbling about the meaning of the word ; but they have one characteristic, that they cannot be carried out under compulsion : you can order a person to carry out this or that muscular movement, to go here and there and to do a great number of different things, but you cannot order him to produce an original idea. It is that character that makes people frightened at the idea of organisation or planning in the field of science. It is because they recognise that science is something different from other human occupation.

The simple reaction to that, the very first reaction which would occur to anybody, if planning may injure science or interfere with its freedom is, ' Of course we must have no planning in science, because originality is the very lifeblood of science and you must not interfere with it.' But if you look at the other side, and see the necessities there are in industry for organised attack on the problems, and when you go further and look into science itself and see the way it has grown, particularly in the last fifty years, you can see that any but an organised attack, even in the most academic centre of science, is hopelessly inadequate, and in fact would fail to give these results at all. We see that the simple solution of saying we will not have any planning is not acceptable, and what we have to do is something very different, and ought to be done scientifically, and that is to arrange the planning of scientific activities so that they do not interfere with or attempt to compel originality. That is a serious undertaking, and in it we would like to have the collaboration particularly of those people who have the strongest sense of the need for the freedom of science. There are the people whom we want in the planning of science, because they will watch over and look out for that freedom.

I think a certain amount of those difficulties have already been removed in the discussions we have had. We have had many of them removed, for instance, in that admirable setting-out that Dr. Goodeve gave us, showing the relative proportion of applied and pure science over the field. But there is another reason which, although fairly obvious, is not sufficiently often stated ; or at any rate does not come up in the arguments. There is what might be called a complex flow-chart in the relations between the fundamental and the applied sciences, and it is of course in that complex flow-chart that a great many of the arguments and misunderstandings arise. For example, you have a pure science, physics, which can have an enormous number of sub-divisions ; and on the other side, in applied science, you have, say, the electrical industry. Or on one side you have genetics, and on the other, stock-breeding. There is clearly a very definite relation between physics and the electrical industry, and between genetics and stock-breeding, but you cannot say that everybody doing physics should do something in electricity, and similarly that someone doing genetics should do something about stock-breeding. In fact, if you look into it seriously the electrical industry also depends essentially upon chemistry, and stock-breeding depends upon a number of other subjects besides genetics, such as physiology.

What that really means for the freedom of science and the position of the individual, is that as there are intermediate stages between the divisions of theoretical science and the operations of industry and agriculture, and it does not happen that a particular piece of research in one has a particular application in the other. Every piece of research can have application all over its own field, and every single requirement in industry sends back lines of enquiry which cover the whole of science. The network needs servicing, that is the important point ; and it is provided by the scheme which we have referred to as background research. Background research is a sort of junction-box which takes in results from different sciences and distributes them to the various services and industrial needs. There is no reason why organisation should not be applied to the scientific and industrial systems as a whole. It is a piece of staff organisation, and it is one of the most urgent problems of the time. There is no reason why such organisation should have a deleterious effect on the individual if one or two major principles are respected.

There are so many things to do and so many problems, and we are so short of workers, that we will never be able to tackle all the problems. We therefore have a chance of securing efficiency in such a way that we make use of people to solve problems they want to solve ; so that no one is compelled to solve a problem he is not interested in. He must be given a choice. I do not think many of those working in war science felt that they were being compelled to do a thing. There were so many fascinating problems that they had no necessity for this, and most of us in war science have enormously enlarged our scientific interests. I had never discovered before the war, for instance, that geography was a real science. If you provide a system whereby a number of attractive choices come up before the scientist, you will always have something to attract them.

The second point is one first put forward by Professor Blackett. It is that, in view of the fact that our real limitation is a limitation of personnel, if anybody wants to investigate anything and to do it himself, and can get a gang of people to help him to do it, no obstacle should be put in the way and he should be given every possible assistance. You cannot have it both ways. It has been said we cannot get on with research because we have not got the people ; and others say we have got the people but have not got the money. The real limiting factor at the moment will be people ; and with due respect to what we have heard this afternoon, the lesson of war with respect to money

is that we succeeded because we had all the time an open purse and ample facilities for research ; now we hear in the hard times of peace the open purse must be tightly closed. But that is a piece of human fatalism which I think is totally unacceptable. I put it to an economist, why is it that we can afford to spend, let us say, as much even, possibly, as two per cent. of our national effort in the middle of a terrible war for science, and can only spend—the figure may have risen—as much as a half to one per cent. in peace? The answer, of course, is that we are tied by certain legal restrictions in peace, which are purely man-made affairs and could be easily altered. I am aware, and everybody in war science is aware, of economic aspects of research which are an apparent luxury in men and lives, but for the needs of victory in war they nevertheless are truly economic. War research is definite in its ends. We were told, ' I am very sorry, we do no research on that machine-gun because we want to concentrate all our research on a 25-pounder for this particular purpose, and you will have to put up with the machine-guns we have in this particular range until we have finished that research.' We work in war with large but always limited resources. The question of priorities has to be managed in war, and is the first essential in peace. One of our objects in the organisation of research is simply the assessment of priorities.

I want from that to come to another aspect of scientific organisation. We have been told over and over again, especially in the last few weeks, that the scientists are a very dangerous set of people who want to rule the State. They want to usurp the functions of government. That is again the same kind of simple-mindedness to which I was referring, with regard to the planning of original work. The scientist, as far as he has had any experience in affairs—and many of us have had that experience during the war—realises what a thankless and what a highly specialised job the so-called ruling is, the actual giving of orders which have to be carried out. It is not a scientist's function, and I do not think any scientist would really want to do it. If you have someone as a director of research, who wants to do it by giving orders, he would be a very bad director of research. Orders may be necessary in business and in military affairs. But the scientist's job is not to give orders, but to find out the circumstances and the conditions in which any given orders are appropriate. The distinction may be in certain circumstances a fine one. There may be certain military operations in which whether a certain thing is done or not is closely determined by the scientist. For example, a commander-in-chief might decide to land his troops where he wished, but he would be a poor commander if he did not take the advice of those who advised him on the weather and the state of the tide when the troops landed.

Over and over again the real choice has to be made without adequate knowledge, and that is where the art of the commander or the business man essentially lies. The scientist cannot give virtual orders except on a basis of complete knowledge. He can only give the best advice he can to others, who must take action on the advice he gives.

My final point is that these distinctions are not absolute. The best work in the war was effected by the close association of scientists and soldiers of all ranks, and that was the great beauty of scientific work in war. The scientist was rather better off than any other military person, in the sense that the obstructive limit of rank did not matter. You could talk to the private or the commander-in-chief, but the commander-in-chief could not talk with a private. We could really range over the whole field, and that mixing between the scientist and the executive at all levels is really necessary to the practical side of the planning of science.

But it also applies inside science, and I think we get over an enormous amount of this difficulty if we introduce one word very much bandied about and misunderstood into science itself, and that is ' democracy.' If we realise that the actual organisation of science has to be far more democratic than any other kind of organisation, we shall really begin possibly to combine the advantages of planning with this absolute necessity of freedom. The best-run laboratories are those which have their own councils and formal or informal discussions, where the director does not direct in any sense other than in the value of his suggestions which are accepted by the people whose ideas are also thrown into the discussion. He does not tell people what to do, but talks about the ideas, and it becomes apparent automatically what must be done and who must do it ; and that gives them a very wide and deep confidence in common work. We shall get over many of the difficulties of scientific education by the same process. I am hopeful that the people who really carry out the education, and give us this body of scientific workers we need, will be the students themselves. That is perhaps because I work in a favourable place in Birkbeck College, where students are all working men and women anyhow, and have that experience to back them ; but I think it can be applied generally, and that in other places there could also be students' and staff committees where we could organise collaboration in the process of teaching, and in that way be able to produce far larger numbers of students to deal with the problems that confront us, and to produce that help in a more responsible manner.

Mr. J. A. Lauwerys.—We have heard that the fundamental problem is one of providing personnel. In the provision of scientific personnel there is a bottleneck, and this bottleneck, it seems to me, seems to become narrower rather than wider in allowing a larger stream of staff to pass through.

The bottleneck consists of science teachers in secondary schools. These are limited in number, and I am afraid that instead of growing in number they may now rapidly diminish ; and I feel sufficiently strongly about this to make this an occasion for issuing a warning on that subject. The total number of science graduates coming into secondary schools in the past was very large. It looked large because little science was being taught in secondary schools and none at all in elementary schools.

Under the pressure of certain social forces

rather than because of the widespread interest in the advance of education, we have now passed an Education Act. This Education Act, in one of its provisions, includes the idea that schools to which children to the age of eleven and sixteen are pupils, shall be called secondary schools, and to implement that teachers in both kinds of schools, those hitherto called secondary, and elementary schools, shall receive the same salaries. I think from one point of view that is excellent and increases the reservoir from which we can draw personnel later on to be trained in universities and technical colleges, but from a nearer point of view it will cause a dispersion of academically qualified staffs who hitherto have been concentrated in secondary schools, and this will make it more difficult to provide instruction to fit people later on to move up to places of higher education. The difficulties could be met if plans were to be made largely to increase the supply of science graduates to teach in schools, but universities already are being called upon to provide personnel for all sorts of other tasks—for the setting up of research associations and industry demands trained scientists, and so on.

As we have heard this afternoon, the general level will have to rise and this increases the competition for science graduates. Do universities contemplate very largely increasing their supply and output of trained scientists? As far as I know, they do not. I have not heard that they contemplate doubling, trebling or quadrupling the output, say, of B.Sc.s. To provide science teachers for all the schools of this country, you would have to multiply the output of science teachers by something like eight. Will those people come from training colleges? If one wanted more science graduates in the schools, one way would be to increase the salaries of the graduates, but now there is a certain dissuasion from taking degrees if you are going to teach in schools. The salary scales accepted are such that you have the choice of training for two years or four years. If you start to teach after four years instead of two years, your salary will be £15 higher, but you will have lost £600 during those two years and you will just strike even with a person of two years' training after twenty years of teaching in a secondary school. This means that a young man in poor circumstances will feel reluctant to enter for science training up to an adequate level. What is one to do in this dilemma? There will not be enough entrants into the universities and technical colleges unless something is done greatly to increase the output of science teachers from universities and training colleges. Science will not be adequately applied to human well-being unless scientific understanding is increased among the people at large.

By visual aids perhaps something can be done in the cinema. We should address ourselves to this problem by methods to teach the people rapidly something about science, and we should use the modern radio more effectively than hitherto, and endeavour to enlist among scientific workers at large a sufficient supply of persons who would be apostles in this crusade.

Mrs. Dora Russell.—What I have to say is concerned with an aspect the last speaker has begun to touch upon—the educational aspect at a lower stage than that considered previously in this Conference.

I am speaking as one engaged for about sixteen years in ordinary education and being very much concerned with international relations. Those are the two angles from which I approach the subject. I want to emphasise very strongly what we might do about the cinema in the practical education of the public in the value and education of science. I can see no reason why we should not have the opening of the cinema on Sunday afternoons with films that have an educational, scientific, instructional and beneficial effect for families.

One speaker spoke of the necessity of an early understanding of science. I was regarded as eccentric because I provided children in my school from five years upwards with the means of understanding and experimenting with scientific material. It is unfortunate that there is not a stronger attempt to bring the beginnings of science into our elementary as opposed to our secondary schools. At that stage the child is interested in the sensory world about him, and may respond to a scientific approach.

The human mind is partly created by the early environment and education. Many psychologists and educators to-day agree that the driving force behind the intellect and the application of knowledge is the most dominant feeling in a given human being. As we must all be aware, probably the strongest motive in human character is the desire to destroy one's enemies, not always through sheer love of destruction, but because we are afraid. Professor Bernal has pointed out the great effect of the war in co-ordinating the entire effort of the community, because we were then inspired with a desire to destroy our enemies. We have seen that scientific research has been enormously stimulated by this turning of national energy to world destruction in two great wars. Such research has not been all destructive; but the creative sciences which arise, as in the care of children, and food, and other matters, are frequently closely co-related with this desire for destruction.

It seems to me that, however vital industrial planning may be, we need research into how to produce human personalities whose primary impulses are not destructive but co-operative and creative. I submit that we know from the work of a number of psychologists and educators at least some of the methods by which this can be done. It is possible by education, especially in the early stages, to rear people whose urge is towards co-operation and understanding, rather than rivalry in the struggle for life. To those who tried to do this a frequent objection made was that people so educated would not fit into the competitive system as we know it. But we have now ample evidence that the competitive world in which we live is self-destroying and if we continue to educate on the old psychological lines it will continue to be more self-destroying. We want far more research, not so much into training, instruction and selection of personnel, as into those means by which we can actually create human personality. It is useless to multiply the richness of scientific achievement if we are driving to

destruction or have no idea of the ultimate end of our society.

Sir Edward Appleton told us that he was often consulted by young scientists about their careers, and found among them a desire to work so that their work was likely to be beneficial in the human sense, and that they showed their interest in that aspect rather than in the salaries they were to receive. At the same time he told us that, in his view, the authority of the scientist did not extend beyond the walls of his own laboratory and the presentation of its results, and he did not look favourably on the dictatorship of science. Our President said that scientists could not be held responsible for the use made of their discoveries, and instanced Professor Soddy's prophecy that the first use of the release of atomic energy would be to create a bomb.

Dr. Goodeve, on the question of the national loaf, showed us that the scientist had to decide whether he should not at some stage be in the position of giving certain instructions or orders, or guidance to the ordinary person. It is clear, therefore, that whatever his personal wish, the authority of the scientist does extend outside the walls of his laboratory. As an educationist I might say equally well, that my authority does not extend outside the walls of the schoolroom. But I would not disclaim responsibility for the results in the outside world of what I taught. Therefore, as members of the public, I feel that we cannot let eminent scientists get away with the plea that they are not responsible. They demand liberty for research ; but I should say to them, as was said by the women who fought for emancipation and the vote, you cannot have freedom without responsibility.

The Lord President of the Council has stressed the individualist nature of our people. The moral responsibility for science rests squarely on the shoulders of all of us and we cannot put it on the shoulders of the State. To do so would be to take a long step towards totalitarianism, and much that I have heard leads me to feel that that is a real anxiety of the future.

We are now trying the Nazis and their collaborators. I need not elaborate the lesson this may have as to our own future procedure. It should logically follow that the leaders of our own State and the scientific experts may in certain circumstances be potential war criminals. We have in our law a provision by which an individual may contract out of military service if he has a conscientious objection. In the state of the world at present any new war must, of necessity, be mass destruction, and the need to examine the individual conscience in relation to the purpose of the State has become incumbent upon everyone.

The world at large is looking to the co-operation of scientists and students of the humanities and statesmen in resolving these two great problems : first, what is the future purpose of our society to be as a nation in the world ; and second, how are we going to create not a mere docile or servile but a co-operative and civilised community of human beings, such as is already envisaged by some of our more intelligent psychologists and educationists. We thank scientists for their part in the war effort, but look forward to their creative activity in peace.

Sir Richard Gregory, Bt., F.R.S.—Mrs. Russell has put forward a point which is embodied in a draft resolution which I am about to propose that this Conference should adopt. No scientist desires to relieve himself of all responsibility for the use made of his discoveries, but only that he should share this responsibility with other citizens.

At the opening of this Conference I referred to this matter in connection with the Three-Power statement of the President of the U.S.A. and of the Prime Ministers of the United Kingdom and of Canada. The resolution approves the principles expressed in that statement, which the British Association may well support as they are humanistic. We cannot, by the constitution of the Association, pass a resolution to take action, except through the Council of the Association. This is the resolution which can be submitted to the Council of the British Association for consideration and action if you wish :

> This Conference called by the Division for the Social and International Relations of Science believes that the statement on the future use of atomic energy, issued after consultation between the President of the United States and the Prime Ministers of the United Kingdom and of Canada, should receive the support of the scientific world as indicating the true approach to the problems, on the one hand, of developing the beneficial applications of atomic energy and of other scientific achievements, and, on the other hand, of preventing their destructive uses.
>
> The Conference requests the Council of the Association to consider the desirability of forwarding a communication to His Majesty's Government in this sense, and of using any other opportunity within the scope of the Association to support the ideals implicit in the statement referred to.

(*The resolution was forwarded to the Council.*)

VICTORY CONGRESS OF L'ASSOCIATION FRANÇAISE POUR L'AVANCEMENT DES SCIENCES

By Prof. J. Verne, Secretary-General

(*Translated*)

After July 1939, when it held a great congress in Liège, the activities of the French Association for the Advancement of Science slackened and passed, so to say, into suspense. But with France liberated and victorious, it was decided without delay to revive its normal activities. On October 20–26, 1945, its sixty-fourth meeting, the Victory Congress, was held in Paris under the presidency of M. Piéron, professor at the Collège de France. By arranging this congress, the French Association wished to show that, throughout the period when means of expression were so cruelly denied to France right up to the present time, when difficulties still exist, the flame of French science has never been extinguished, in spite of all the efforts of the forces of occupation during the hard years of oppression. The Association called upon workers in every branch of science to take note of this occasion, and invited scientists of the allied and friendly nations to renew the co-operation, formerly so productive, but too long interrupted. For these reasons the Victory Congress had a significance of the highest importance, and foreign scientists fully appreciated this, for many of them answered the call of the French Association. The British Association for the Advancement of Science sent six eminent representatives: Sir Richard Gregory, its President; Lady Gregory, representing women members of the Association; Sir Thomas Holland, a past-president, formerly Principal and Vice-Chancellor of the University of Edinburgh; Sir Edward Appleton, Secretary of the Department of Scientific and Industrial Research; Professor E. N. da C. Andrade, senior professor of physics in the University of London; and Lieut.-Colonel W. Campbell Smith, of the British Museum (Natural History).

The American Association for the Advancement of Science was represented by Dr. Albrecht, Vice-President of the Association, Professor in the University of Missouri; Dr. A. Worcester, Professor in the University of Nebraska; Dr. Stanley A. Cain, Professor of Botany in the University of Tennessee and Captain Alvin R. Grove, Professor of Anatomy and Physiology of Plants, the State School of Forestry, Pennsylvania.

The U.S.S.R. Academy of Sciences by MM. Nesmeianov, Academician, and Landsberg, corresponding member of the Academy of Sciences.

The Swiss Academy of Sciences by Professor G. Tiercy, Director of the Observatory of Geneva; Professor P. Wenger, School of Chemistry, Geneva; Professor E. W. Collet, President of the Swiss Society of Geology, Geneva; Professor F. Chodat, President of the Swiss Society of Botany, Geneva; Dr. M. H. Mislin, Secretary of the Swiss Society of Zoology; Professor Rothlin, Faculty of Medicine, University of Basle; Dr. Glasson, Director of Studies in the University of Geneva and Professor Gigon of the Faculty of Medicine, University of Basle.

The Argentine Association for the Advancement of Science by M. Ranwell Caputto.

The French-Canadian Association for the Advancement of Science by M. Marcel Raymond, Assistant Secretary of the Association.

The Netherlands Government by MM. Raven, Professor of Zoology; Clay, Professor of Physics, and Backer, Professor of Chemistry.

That of Sweden by MM. Svedberg, Edlen and Petren.

That of Norway by Madame Ellen Gleditsch, Professor of Chemistry in the University of Oslo.

That of Czechoslovakia by Professor Rudolf Barta, Professor in the Polytechnic School of Prague; M. George Barta, Assistant in the Polytechnic School of Prague; M. Atamar Quadrat, Doctor of Engineering, Polytechnic School of Prague; M. Ilkovic, Professor in the University of Bratislava; M. Valentin, Professor in the University of Bratislava; M. Hlawatij, Professor in the University of Prague; M. Hostensky, Professor in the University of Brunn and M. Horak, Professor in the Polytechnic School of Prague.

Belgium was represented by MM. Dehalu, Administrative Officer of the University of Liège; Libois, de Bèvère, and Geheneau.

Poland by M. Kozlowski, Professor in the University of Warsaw, and M. Eugène Geblewicz, Assistant Lecturer in the University of Lodz.

The delegates chosen by Rumania and Denmark were unable to be present at the Congress owing to difficulties of transport.

The general committee was made up of prominent scientists, politicians and industrialists, and eminent Parisian scientists presided over the Sections.

The Congress opened with a solemn inaugural session in the grand amphitheatre of the Sorbonne.

M. Le Troquer, President of the Municipal Council of Paris, welcomed the members of the Congress, and particularly the foreign delegates, whose representatives then read or deposited addresses to the Association.

M. Frédéric Joliot-Curie, Professor in the Collège de France, and Director of the Centre National de la Recherche Scientifique, set forth the problems of scientific research in France, showing what has been done already to co-ordinate scientific work, to help research workers, and to organise research. He also indicated what remains to be done in order that research in France may take the place which belongs to it and which it should occupy in the life of the nation. The recent example of the atomic bomb illustrates the important influence of scientific work upon the destiny of the nations and of the world.

M. Justin Bescançon, in the Faculté de Médecine and President of the French Red Cross, dealt with malnutrition during the war period. The war and the German occupation in the countries overrun by the Nazis provided a real and deplorable biological demonstration by creating a state of famine. The manifestations of this state were various—emaciation, œdema due to want, osteopathic affections and symptoms due to lack of vitamins. The means available to combat these conditions were always imperfect and there had been a terrible recrudescence of tuberculosis.

Finally, M. Piéron, President of the Association, addressed the meeting. He explained the motives which had actuated the Association in holding the Congress. He thanked the delegates of the allied and friendly countries for having come to the Congress in such numbers despite all difficulties. The subject of his discourse was that of time from the standpoint of psychology.

In biology, the dominating characteristic of time is irreversibility, which physicists can often neglect in their equations, and there is a close affinity between time and life.

The action of time, too often neglected, is fundamental in the processes of sensory activity, where quantities are in question which show progressive and regressive evolution of the observed intensities. Variations of duration may manifest themselves in spatial form and, conversely, variations in space may assume an aspect of time : certain examples were given. At a level below perception, differences of the order of a hundred-thousandth of a second are effective, while the perceptive discrimination of time is a thousand times less acute.

Psychological time, despite the illusion of continuity, is made up of ' instants ' which represent, as it were, atoms of time, in the direct appreciation of durations limited within a range of some seconds. Beyond this range, indirect perceptions rest upon physiological periodicities, modelled in general upon physical or social rhythms, with notable affective influences. For periods of some hours appreciations of time are intellectual and are based upon a wealth of experience, which entails the apparent acceleration of the passage of time as age increases.

Subjective time, considered as true time in Bergsonian philosophy, is not grasped by purely immaterial intuition, for it is governed, as with the animals, by the law of acceleration with temperature, which applies to the chemical substratum of neurobiological processes.

There is in reality no such thing as ' true time ' ; the idea of time dissociated by abstraction from the only ' reality,' that of phenomena, is acquired with difficulty by the child under the influence of a social system of education, and the dimension ' time ' of the physicists, an abstraction which diverges in a striking way from ordinary ideas, reaches a profound truth to which the success of scientific predictions bears witness.

On the Sunday morning a series of visits was arranged : to the Pasteur Institute, the Palais de la Découverte, the Musée de l'Homme, the Zoological Park at Vincennes, and the Musée du Louvre.

On Monday, October 22, the work of the Congress proceeded. This work was arranged thus : the mornings were devoted to sectional conferences, the afternoons to joint meetings of several sections to hear communications on borderline subjects not within the purview (often too limited) of the sections.

Lastly, each day at the end of the afternoon sessions, there were general discussions of wide compass addressed to the whole body of the Congress.

The essential aim of the statements presented was to provide a balance-sheet of work done in each department of science by French research-workers during the years of the enemy occupation, 1940–45.

The general discourses were as follows :

Cave Life by M. Jeannel, Professor in the National Museum of Natural History, creator of the branch of science which embraces these studies.

The astonishing variability of microbes and its significance from the standpoint of general biology, by M. Boivin, member of the Academy

of Medicine and Chief of Staff at the Pasteur Institute. Bacterial cells, viewed from the combined morphological and physiological point of view, possess great plasticity. The reversible and irreversible transformations which bacteria are capable of undergoing under various influences are of great importance in the framework of the notion of species. The consideration of antigenic structure and of the body of constituent enzymes led to the discussion of recent American work and of results obtained by the speaker himself, showing that an active principle of a nuclear character may be exhibited by each bacterium, capable in its turn of inducing the appearance, in other bacteria, of the antigenic type and enzyme-equipment of the primary bacterium. Viruses also present wide variability of pathogenic power.

The conference on Radiology in France from 1940–1945, addressed by M. Lacassagne, Professor in the Collège de France and Director of the Radium Institute, paid tribute to the memory of French radio-biologists who died in German prisons or concentration camps: Holweck, Wollman and Mme Wollman, Vles, Reiss, Florence, Crolan, Segal. The work accomplished by these scientists and their colleagues is arranged under four headings: quantum radiobiology, the role of oxygen in the production of radio-lesions, the relations between radiations and cancer, and finally the biological use of artificial radio-elements, and in particular the fixation of radioactive iodine in the thyroid.

The phenomena of self-oscillation formed the subject of the address by M. Rocard, Professor at the Faculté des Sciences de Paris, who presented an account of the progress made in France during recent years towards the understanding of these phenomena. Whereas formerly the workers in this field were content to discuss in a formal way the stability of solutions of the differential equation governing an oscillatory phenomenon, we have now succeeded in classifying the causes of self-oscillation. It is well known that in a system with one degree of freedom the cause of self-oscillation is the introduction of a negative resistance. In the case of many degrees of freedom it has been recognised that, while a negative resistance always constitutes a possible cause, self-oscillation is caused even in the absence of any positive or negative resistance by the approach of two proper frequencies which merge when certain parameters vary. Luckily, it can be shown that in every passive system (masses and springs, or self-inductions and capacities, etc.) coupling always separates the proper frequencies, but if we introduce relays, relations which are not holonomic, forces which do not depend on a potential, we find that the possibility of self-oscillation is created by this mechanism, even if these forms are always in quadrature with the velocities. Furthermore, the following very important theorem has been demonstrated: if in such a system we add, in an endeavour to damp it, resistances or frictions, we only make self-oscillation easier, in any case so long as these resistances do not modify too much the proper frequencies. Applications of this work have been made to the vibration of the wings of aeroplanes, to the sway of locomotives, to various phenomena of rolling and so on.

Among inter-sectional addresses, reference should be made to those on electro-encephalography (A. Baudouin, Fessard, Titeca), in typology (Delaporte), on the application of the calculation of probabilities in biology, on Mendelian biology and mathematics (Malicot).

The sections of geophysics (M. Coulomb), of geology (M. Lanquine), of geography (M. Cholley), of biogeography (M. Sorre) also held very fruitful meetings.

Special notice is due to the address on the destruction and reconstruction of the great French ports (M. Boucher), and on war damage in France and the problems of reconstruction which lie ahead (M. Sasportes).

Lastly, the sections of psychology (M. Fessard), and education (M. Wallon), studied the problems of the orientation of teaching and collective tests.

Merely to enumerate the communications to the sections would occupy several pages. They do honour to French science.

The closing session took place on Friday, October 26, at 3 P.M., in the grand amphitheatre of the Faculty of Medicine. M. Cholley, Dean of the Faculty of Letters, gave an address on agrarian systems and rural settlement. The relationship between any agrarian system and the form of settlement associated with it is well recognised, as also are the exceptions to such relationship. This relationship, however, is not intelligible unless these two phenomena are considered as a true biological and anthropological synthesis which, like all biological syntheses, conforms sometimes to strict laws determined by its structure or by the influences of physical and biological environment; and sometimes, like all manifestations of life and particularly of human activity, is liable abruptly to break the cycle or rhythm which it has followed down to a given moment, to diverge in another direction.

The elements which compose the actual structure of the syntheses are four in number: the distribution of population, to be viewed according to density but more particularly according to social structure—cultivation system (plan, rotation, etc.)—the soil and its composition—settlement.

Between these elements there exists so close a relationship that if one of them varies the others are altered. Many examples of this may be cited: the introduction of a new crop in Brie, sugar-beet, caused in the nineteenth-century modification of the rotation of crops which had repercussions on the agrarian system, then on the social structure, and even on the demographic conditions of settlement. Examples might also be cited showing the effects, on the structure of the synthesis, of modifications in demographic values or in the social organisation of the distribution of population.

Like all biological and anthropological syntheses, agrarian syntheses reveal themselves in phenomena of spatial extent; once organised they tend to gain ground as plant-groups do (e.g. the Lorraine and Beauceron systems). They reveal, moreover, a real dynamic force which can be measured not only by the value of products but more effectively by the coefficient of population and by the standard of living determined by that of productivity.

The synthesis, moreover, is in a state of constant evolution, which may develop regularly, or in a cycle, with stages of youth, maturity, and old age from the standpoint of demography and of labour; but it may also exhibit 'missfires' or abrupt changes of condition marked by serious crises.

Lastly, like all biological syntheses, our agrarian syntheses adapt themselves to natural conditions, in a sense difficult to define except with a full knowledge of those conditions—climate, soil, biological factors—to which such syntheses conform. Examples might even be cited of syntheses which appear to have achieved a positive paradox in relation to natural conditions.

The purely historical method which hitherto has guided our researches, and in all countries has yielded noteworthy results, is therefore insufficient. The study of the problems of agrarian systems should be inspired by biological method, which consists of collecting observations of all recognisable types of agrarian syntheses in every part of the world, while seeking to understand their structure and changes in such a way as to distinguish the conditions which determine them.

It should be added that enquiry on these lines in 'new' countries is a matter of urgency, especially where the unifying process of colonisation so quickly effaces evidence of the past, even the most recent.

In the course of the executive meeting, the *bureau* of the Association was reconstituted. M. Montel the eminent mathematician, Dean of the Faculté des Sciences de Paris, was elected President for the year 1946. The congress over which he will preside will be held at Nice. M. Fage, Professor in the Natural History Museum, was elected Vice-President.

The Congress concluded with a stirring tribute to the conquest of the Atlantic bridgeheads in 1945, paid by M. Jacobson, past president of the French Association for the Advancement of Science and of the Society of Civil Engineers of France. In this conquest Colonel Jacobson played an important part in command of the artillery of the detachment of the Army of the Atlantic under the orders of General de Larminant.

In the course of the Congress, various entertainments were arranged for those who took part—a performance of *Caligula* at the Hebertor Theatre, a reception at the Hotel de Ville, and a banquet, in the course of which moving addresses were delivered.

APPLICATIONS OF SCIENCE *(continued)*

THE PLACE OF SCIENCE IN TOWN AND COUNTRY PLANNING

By Professor L. Dudley Stamp

I. The Scope of Town and Country Planning.

It was only in 1909 that Parliament passed the first legislative measure dealing with town and country planning. This was the Housing and Town Planning Act which enabled councils of Boroughs and Urban and Rural Districts to prepare town planning schemes for land actually in course of development or likely to be so used. A more comprehensive Town Planning Act was passed in 1925, but was repealed and re-enacted with additions by the Town and Country Planning Act of 1932, which came into operation in 1933. It might therefore seem that the whole question of town and country planning is something new in Britain. This indeed is a view commonly but quite erroneously taken.

The face of Britain bears very definite marks of both urban and rural planning of past ages. The difference is that in the past such planning was the result of private enterprise and in most cases was made possible by the existence of a small number of large landowners controlling very extensive tracts of land. Undoubtedly the layout of the mediæval manor was the result of conscious planning, and in due course these plans were crystallized into a definite field pattern with the coming of enclosures, and are reflected in the present-day farm boundaries. At a later stage the great mansions which date from Georgian and Regency times introduced a new note, the result of the conscious art of the landscape architect. The clumps of trees which crown so many prominent hill-tops, just as much as the stately avenues of lime and elm, are present-day survivals of rural planning of this period.

Similarly with the towns; for whilst it is true that many of our villages and towns are the result of unplanned growth and increase in accordance with functional needs, we have many examples, if not of whole towns at least of major portions of them, planned most effectively on a comprehensive scale. There are the outstanding examples of Bath and of the squares and terraces of much of the west of London.

What, then, is the difference of the present day? For good or evil, the large landowner has ceased to be the dominant force which he was in the past. It is estimated that some five million householders in Britain are actual property owners. Indeed, before the outbreak of World War II no fewer than three million had actually purchased their homes

with the aid of Building Societies' loans. Thus a very large proportion of the people have a definite stake in their land as owners of at least a portion of it. They still have to learn to work together for the common good. In other words, the rise of democracy has brought with it the necessity for town and country planning as a function of the democratic state.

One of the great features of this country has always been the strength and importance of local government units. Local patriotism and *esprit de corps*, often almost violent in their partisan enthusiasm, have been the dominant factors in much of the development which has taken place throughout the country. It is not surprising, therefore, that the Town and Country Planning Act of 1932 did not set up anything remotely approaching planning by the State. The initiative for the preparation of planning schemes rested with local authorities. When they had drawn up—either with the assistance of outside expert advice, or through their own officials—what seemed to them good plans for the development of their area, those plans had to be submitted for approval to the Planning Branch of the Ministry of Health. The Minister, after undertaking, if necessary, local enquiries and hearing objections, could then approve the scheme, which became operative, or could refer it back for amendment; but there was no power of initiation. The Minister could not compel any local authority to prepare a planning scheme. Still less was there any co-ordination to secure a national scheme of development. In many respects the results of this measure, in the five years before the outbreak of war upset or interrupted the whole, were interesting. Nearly all plans revealed an expansionist mentality of the local authorities. They all thought in terms of expanding population, expanding industry, and ever-increasing size. It was taken as axiomatic that a place would grow, for had not that been the experience at least of most for many decades past, and was it not also the hope of those that had not experienced expansion to date? Thus we find that by the outbreak of war in 1939 approved and operative schemes covered only about a million acres of England and Wales, but that schemes were in course of preparation for a further 26 million acres, or rather more than two-thirds of the whole surface of the country. What is interesting is that if the provisions for increased population envisaged under the various individual schemes are added together, allowance was made for a population of nearly 300 million people additional to the present population of 41 million. This palpably absurd result pointed to the necessity for a revision of the whole approach to planning, for not only was it ridiculous on paper, but it had also some serious effects in practice.

Land which was zoned for housing in a town planning scheme suggested to the present owner or occupier an instability of his present position. Quite naturally when a farmer found his land thus zoned he hesitated to incur the necessary capital expenditure to improve his buildings or the necessary recurring expenditure to keep his land in the best possible condition. There was a marked tendency for the land on the fringe of towns to show deterioration of management and indeed to pass into waste, just as much as land actually did when it was brought up and held for future building purposes.

The need for land planning on a national basis was further emphasized when the Royal Commission on the Geographical Location of the Industrial Population, under the chairmanship of Sir Montague Barlow, issued its Report recommending the encouragement of a policy of dispersal of industry. As a natural corollary Lord Reith, as first Minister of Works and Buildings (to which Ministry the Planning Branch of the Ministry of Health was in due course transferred) set up in conjunction with the Minister of Agriculture the Committee on Land Utilisation in Rural Areas, under the chairmanship of Lord Justice Scott. This Committee was charged with the duty of considering 'the conditions which should govern building and other constructional development in country areas consistently with the maintenance of agriculture, and in particular the factors affecting the location of industry, having regard to economic operation, part-time and seasonal employment, the well-being of rural communities and the preservation of rural amenities.' The Report of that Committee, popularly known as the 'Scott Report' and presented in August, 1942, left no doubt whatsoever that its members realised to the full the necessity for planning on a national scale. For the carrying out of their numerous recommendations they suggested a Central Planning Authority under a non-Departmental Minister of Cabinet rank, assisted by a small expert staff whose function should be that of co-ordinating the postwar planning functions of all Ministries concerned with the use of land. Actually the Government of the day set up a Departmental Ministry, the Ministry of Town and Country Planning, which in its turn took over the planning functions from the Ministry of Works and Buildings and was charged with the essential work of co-ordination of land use.

It would be a mistake to imagine that national planning is new in Britain. The supreme example of national planning in this country we owe to the Romans, who laid out their scheme of national roads, nearly all of which have survived as important highways in our modern system of communications. They quite consciously located and planned their major civil towns and military centres. At a later date the division of both England and Wales into convenient units, each under an Earl or Count responsible to the Crown, can be described as an example of national land planning. On the other hand the smaller unit, the parish, grew up rather in response to local needs, since both the shape and size of the parish reflect the character of the land and the needs of the rural population.

That national planning has once again become a matter of supreme importance and urgency was evidenced during the war, when the imminence of enemy attacks from the sea and air involved a national policy of industrial location. The dispersal of industry envisaged by the Barlow Report became almost overnight an accomplished reality for strategic reasons. It would seem to be equally clear now that if we are to avoid the re-creation of depressed areas in different parts of the country there must be conscious land planning on both national and local scales.

In essence, town and country planning should aim at securing the right use of every acre of the land surface in the national interest; a use designed to satisfy the varied needs of the people; designed to secure a proper balance between town and country; to avoid on the one hand the undignified amorphous sprawl of the urban units, thereby creating innumerable natural problems of their own; to avoid on the other hand the complete spoliation and suburbanisation of the whole countryside and the ruination of its capacity for agricultural and forestal production.

It is easy to talk about the right use of land and of the varied needs of the population. It is necessary to examine with care both what we consider are the essential needs and to deduce therefrom what is the proper use of land.

As human beings we have at least five basic needs.

In the first place, because so much else depends upon it, we may put the need for work, for employment, and this postulate immediately involves the correct location for industry. Quite clearly the location for industry must be so chosen as to secure the maximum efficiency in a competitive world provided that the maximum efficiency is not secured at the sacrifice of the workers in the industry itself.

The second need is obviously that of a home, and since the homes must be provided in the right relationship to places of work, housing needs are dependent upon the settlement of the problem of industrial location. It is true that at the present time, with an acknowledged shortage of some four or five million homes, houses may be built almost anywhere, and they will be needed, but that only applies to urban replacements and perhaps to the first instalments of these. Very soon it will be of the utmost importance to know exactly where the additional homes are needed. It is true also that we should have learnt that the provision of houses is only part of the establishment of satisfactory homes. They must be related to shopping and amusement centres in such a way as to afford the opportunities for a balanced existence within a community for their occupiers.

Third amongst the prime essential needs must be put food, and here the old cry of 'cheap food' needs to be balanced with considerations of quality and nutritive value, and it is still extremely difficult to assess in monetary terms the relative value of vegetables fresh from the garden with the same articles after a passage through a system of markets and distributing organisations, perhaps after periods of transport in cold storage from distant areas. Closely linked, of course, with the land for agricultural production is the provision of other parts for the growth of raw materials, and it is here that the function of forestry is linked closely with that of agriculture.

The fourth primary need of mankind is recreation, too often regarded even now as a luxury rather than as an absolute necessity of life. Indeed the whole range of the spiritual needs of man are often passed over as being luxuries which we may or may not be able to afford. The provision of open spaces and playing-fields in town-planning schemes, or the conservation of tracts of open land, are still regarded as desirable extravagances which perhaps we ought not to afford, instead of being basic to our continued existence.

There is, of course, also the need of land for purposes of communication—for roads and railways, for air-fields, and one must add for purposes of defence or preparations for defence.

It must be the purpose of planning to see that land is allocated in proper proportion to satisfy each and all of these needs, and we come to the principle which may be called the 'principle of optimum use,' the determination of what is, in the balance of national interest, the most important use of any given

piece of land. This is of supreme importance in a country such as Britain, where the total area of land available is strictly limited. Taking England and Wales there is less than one acre per head of population, and even including the wild and largely uninhabited moorland in the Highlands of Scotland, over the country as a whole there is only about 1¼ acres per head. As a result of this density of population or pressure of population on the land we should perhaps rather stress the principle of multiple use—of securing at least for much of the open land not only one use but several. Thus a tract of hill moorland may serve as a grazing ground for sheep and the maintenance of healthy stock ; it could at the same time serve as a gathering ground for the water supply of a great city ; and, despite what may be urged to the contrary, it can serve as an area for walking and exercise for that proportion of the population that finds healthy and happy enjoyment in that most valuable of all exercises—walking.

II. A Dual Approach to the Problem

To the whole great problem of land use, which is in fact the problem of town and country planning, there are two main approaches. One may be called 'analytic,' the other 'synthetic.'

The analytic is that which starts from detailed investigation of the present position, which seeks to analyse its character and seeks to determine causes. It is the method which would urge the essential importance of very thorough surveys of the present and past position before attempting any planning or reconstruction for the future.

There can be no doubt of the scientific justification for such a procedure. There are only two dangers. The first is that having carried out the survey and having determined the factors which have led up to the present position the work is regarded as complete, instead of which the trends which have been discovered in the course of the survey must either be encouraged to secure a better development in the future, or, if they are trends shown to be undesirable, they must be eliminated by positive action.

Another curious danger is that so often surveys are limited to pathological cases. Where things are obviously wrong, where decay and decadence are obvious—in industry, in housing conditions, in employment, or in health—it is perhaps natural that a survey should be carried out in order to determine what is really wrong, and how the position can be improved. We hear far less frequently of surveys in those cases where things appear to be going along on the right lines and the life to be satisfactory, or where there is obvious development and prosperous growth. It is, in fact, just as necessary to carry out detailed surveys that we may learn the factors leading to healthy development and thus be able to apply them elsewhere.

The synthetic approach to the problems is complementary rather than contradictory to the analytic. In many ways it is the more scientific. It should be possible to take the results of work in many different scientific fields and to apply the findings to the problems of land use and planning. It is only by so doing that one can envisage the development of new lines of action which could scarcely be revealed by the analytical method in any given area. An obvious example is the study of population trends as a whole, which give the clue to the whole of the housing needs for the future in a way in which no local analytical study could do.

III. Analytical Studies

Analytical studies have been carried out in a considerable number of towns and cities in this country. An outstanding example is the *New Survey of London Life and Labour*, organised by the late Sir Hubert Llewellyn Smith, under the auspices of the London School of Economics, and carried out in the inter-war years. This survey brought up to date the famous pioneer social survey of Charles Booth. Similar social surveys are associated with Dr. H. A. Mess on Tyneside and with the University of Liverpool. As an example of field investigations directly undertaken as a basis for replanning of blitzed areas may be mentioned that organised by Mr. Max Lock of the City of Hull and later by him and his team for Middlesbrough. It is perhaps not generally appreciated that similar methods are applicable to rural conditions, but they have recently been applied by Dr. C. S. Orwin to an area of the Midlands. In the book *Country Planning* he has given an analysis carried out by a team of research workers of an area of some 24 square miles which, though described anonymously, can readily be identified as a tract of the Cotswold Uplands between Banbury and Chipping Norton.

Turning to analytical surveys on a national scale we have a number of examples. As part of the national drive for increased agricultural production the Ministry of Agriculture organised a Farm Survey in 1939, the primary purpose of which was to classify roughly the efficiency of farms or farmers. They were grouped as A (good), B (average), and C (poor), and it became one of the functions of the County War

Agriculture Executive Committees to upgrade all farms and to secure the elimination of the C farmers—if necessary (which fortunately was not often the case) by drastic means. Realising how useful detailed information about every farm in the country can be, the Ministry organised the elaboration of this scheme which became the Farm Survey, 1940. Every one of the 300,000 farms in England and Wales became the subject of a detailed questionnaire covering a wide range of questions, partly of fact, such as water supply or electricity supply, partly of opinion, as in the assessment of quality of land, efficiency of layout, and so on. Combined with the returns of stock and crops made by every farmer annually on June 4, the 1940 Farm Survey gave a picture of every holding in the country. The value of this picture was enormously increased by the fact that the area of the farm was recorded on 25-inch or 6-inch maps at the same time. With the questions asked it is clear that the primary records must remain confidential, but the Farm Survey affords information basic to any re-organisation, whether of farm units or of farming practice in the country. The results are now being studied statistically and in other ways for publication of general results.

Another very interesting survey on a national scale was the Grassland Survey organised by Sir George Stapledon and Mr. William Davies over the whole of England and Wales in 1940. This is not a survey of grassland from the point of view of the ecological botanist so much as a survey from the point of view of the scientific agriculturist. The simple grading of lowland pastures is based upon the proportion of the nutritive perennial rye-grass. It is in essence a survey of the then-existing standard of management rather than of the intrinsic capacity of the lands, but it does tend to bring out the distribution of those lands which could, and in some cases do, support the best grasslands, whilst the results were directly used as a basis of advice to farmers as to how to improve the carrying capacity and nutritive quality of their pastures.

A survey of nation-wide importance covering the whole of England, Wales, Scotland, the Isle of Man, and the Channel Islands is the Land Utilisation Survey of Britain. This survey was developed as an independent research organisation under the auspices of the University of London, London School of Economics, in 1930, and its primary purpose was to record on 6-inch sheets the then-existing use of every field and piece of land in the whole country. The work was carried out entirely by volunteers and, involving as it did no fewer than 22,000 field sheets, the task may be described as colossal. The greater part was recorded in the years 1931, 1932 and 1933 and the whole field survey was completed before the outbreak of war. It had thus become a picture of land use in Britain in the 1930's, at the time which may well be a *nadir* in the whole history of British agriculture. The survey covered urban areas as well as rural and the classification of land was a relatively simple one. The degree of detail actually shown by field surveyors on the manuscript 6-inch maps varies, but the field work was checked and edited and the results reduced to the scale of one inch to one mile for publication. The work of publishing the 1-inch maps has gone on steadily, so that about 120 sheets have been issued, and all those covering England and Wales will shortly have been published. The published maps show six or eight main categories of land. Forest and woodland is shown in dark green and the general character of the woodland is evidenced from the underlying symbol of the outline Ordnance Survey maps which are used as the base map. Heathland, moorland and rough grazing (broadly speaking land which is agriculturally sub-marginal) is shown in yellow, and there again, by a study of the position in which such land occurs, it is often possible to see a a glance the reason for its low degree of utility—salt marshes, marshland liable to flood, stand out clearly from abandoned arable land on poor soils or from the natural mountain moorland. The land which at the time of the survey was under the plough or sown with rotation grasses is shown in brown, whilst permanent pasture is indicated in light green. The pattern which is given by the relative proportion of brown and light green is a simple indication of the great variety of British farming. Houses with gardens sufficiently large to be productive of fruit or vegetables are shown in purple, whilst orchards are separately indicated by purple ruling, nurseries by purple cross-hatching. Land agriculturally unproductive, which includes industrial works, closely spaced houses, main roads, and some land actually completely waste, is shown in red. It is interesting to contrast the red of the old closely knit industrial towns of the north with the more modern towns of garden city type which show up mainly in purple with just a small nucleus of red.

This picture of the position as it was in the 1930's has been made the subject of detailed analysis in the Report of the Survey in course of publication in 92 county parts and a summary volume, under the general title of *The Land of Britain*. Since any planning for the future must start from the present position the intricate picture of the

land use of Britain shown on the Land Utilisation Survey's maps must be the starting point for any future development.

Complementary to the Report of the Survey is the Types of Farming Map of England, Wales and Scotland and Explanatory Bulletins, which were prepared in 1939 in England and Wales by the Economics Branch of the Ministry of Agriculture and Fisheries, and in Scotland by the Land Utilisation Survey in conjunction with the Department of Agriculture for Scotland. These maps, published on the scale of approximately 10 miles to the inch, were prepared on an economic basis, but again tend to emphasise the extraordinary contrasts in type of farming between one part of Britain and another.

The factors which have determined the present use of the land may be considered as falling into three groups:

(*a*) The physical or more strictly geographical factors.
(*b*) The historical factors.
(*c*) Social and economic factors, using the word 'economic' in a somewhat restricted sense.

(a) *Physical or Geographical Factors.*

The separation of the influences of the geographical factors is particularly work which falls into the sphere of the geographer, since it is necessary not only to separate and distinguish the influence of each factor, but to assess their relative influence. If one approaches from the point of view of one only of the factors concerned, there is always the danger of the over-emphasis of that particular influence. The geographical factors may be said to comprise broadly the following:

(1) Access and accessibility.
(2) Geology and structure, including the disposition of minerals of economic importance.
(3) The relief, or form, of the ground.
(4) Soil.
(5) Climate.
(6) Biological factors, particularly the effects of natural vegetation.

In any given area it is often obvious which of these factors has exercised the dominant influence. A few examples will suffice. In one of the smaller islands of the Outer Hebrides the overwhelmingly important factor is one of access, and it is the *position* of the area concerned which is of first significance. Despite the various modern developments in transport and communication, ease of access remains of outstanding advantage to the area concerned. It may well be asked, 'Ease of access from what?' Broadly speaking, from the main centres of population.

The overriding influence of geology and structure is quite clear in the case of a coalfield, where the whole surface utilisation and economic organisation of the area is dependent upon the existence and exploitation of the coal. The form of the ground is clearly the dominant influence in the mountainous areas. Elsewhere its influence is ever present, if more subtle and less obvious.

The influence of soil is one which is far less understood, but nevertheless fundamental.

So far as climate is concerned one is left in no doubt as to its major influence in determining the different type of farming in the wetter west of our country compared with the drier east. There is growing appreciation of the role played by small local differences, and for this reason the study of micro-climates is assuming marked importance. These factors are considered in more detail in an ensuing section.

(b) *Historical Factors.*

The historical factors underlying present-day land use are varied in character and often can only be revealed as a result of long and patient research. Accidents of land ownership seen in the existence of large private parks would seem to be obvious, but so often it is found that here the historical factor merely reinforces the natural factor, in that very many of the great estates of this sort are situated on land which is intrinsically poor and was not regarded as suitable for cultivation. The same of course applies to the remaining common lands. It may be regarded as an accident that they have remained unenclosed, but it is usually because of the inherent poverty of the land that such is the case.

There is no doubt, however, that the general pattern of land use as well as the general pattern of settlement in this country is the result of factors important at the time (for example the navigability of rivers through the Midlands of England at the time of the Anglo-Saxon invasion) but which have lost any real significance to-day. The field pattern in many parts of the country reflects the enclosure of cultivated strips as they were arranged in the old open fields and is not related to present-day needs Further, it is often found that the present use of a tract of land is due to a reputation which that land gained in some bygone and forgotten age, but its reputation has been handed down by word of mouth through generations of farmers and generally accepted by them. During the war there have

been innumerable examples of the cultivation of crops on land which local opinion had always held to be virtually useless.

(c) *Economic and Social Factors.*

Looking at the general position of land use historically, one is struck by the great stability of land use on the *best* land and on the *poorest* land. Really good land, suitable for ploughing and cultivation at all seasons, was well known to the mediæval farmer, who had a flair for finding such land. Despite the economic vicissitudes of the intervening years such lands have remained in cultivation from those days to the present. Similarly with the poorest lands. The uncultivated mountain moorlands have remained as such through the centuries, and so have the lowland 'rascally heaths' which were regarded as unsuitable for cultivation in the past and have often remained untouched to the present day, even under the stress of wartime conditions and with all the advantages of modern manurial knowledge at hand. Similarly with a great deal of the remaining woodland and forest of the country. Its character and position and area have changed little through the centuries.

On the other hand, the maximum of change has always taken place on land of intermediate quality. Land, as William Cobbett would have said, which it pays to plough in 'dear-corn' times, is abandoned at other times and becomes agriculturally sub-marginal. Hence the economic factors, in the narrower sense (referring especially to fluctuation in prices of agricultural produce), have had their maximum influence on land of intermediate quality.

Naturally the changing structure of society has been reflected in land use. The break-up of the large old estates, the increase in numbers of owner-occupiers of all types of land, are too obvious to need stressing. It is interesting, however, that the consolidation of small holdings has to a very large extent balanced the break-up of other units, so that taken over the last seventy or eighty years the most stable feature of all in the rural parts of Britain is the number and average size of farm units. Whilst the labour force employed by farmers has enormously decreased, the 300,000 farmers operating to-day differ little in number from the farmers operating in 1870.

In the analytical study of existing land use it is of the utmost importance to bring into consideration all these factors which are involved, for the greatest mistakes are made when one group is considered and the others neglected, and this is the danger of the purely geographical or the purely historical or the purely economic approach.

IV. The Synthetic Approach

In the preceding section it was pointed out that the present land use of the country is the result of the action and interaction of a number of different factors. Once this has been determined and agreed it is clearly possible to approach the whole problem from the other end by taking the factors concerned and studying them *per se*, assessing their existing influence and then going further to suggest the influences which they will exert in the future. In this way practically every branch of science has an important and vital contribution to make to the basic research which must underlie good town and country planning. It is safe to say that at the present day any national concept of town and country planning is held up by incomplete scientific data. It is true that the data required for this particular purpose are often data which have not so far seemed of supreme importance in the science concerned, with the result that the essential investigations have been shelved or pushed on one side by other needs apparently more urgent. We may examine the contributions which may be made by some of the sciences falling within the special purview of the British Association.

(a) *The Contribution of the Geologist*

The distribution of minerals of economic importance must clearly exercise an overriding influence on town and country planning. Very broadly, as was suggested in the Scott Report, economic minerals can be divided into two groups.

(1) Those of which the whole deposit is of importance and as far as possible will eventually be worked. Quite clearly the country will eventually need to work all its coal resources, its deposits of metallic minerals and at least all the medium and higher-grade iron ores. Town-planning schemes must in the national interest be fitted into the economic exploitation of such minerals. This has not always been followed. In fact there are in existence town-planning schemes which would involve the complete sterilization of very large deposits of coal and iron ore. It is clearly the function of the geologist to indicate the exact location and the extent of such minerals so far as is known and to present the data in such a way that they can be interpreted by the town planner. In conjunction with the mining engineer comes the need of indicating areas liable to subsidence or to drainage interference when the

minerals are worked. That a great deal remains to be done in this whole field has been evidenced by the result of exploratory borings for oil during the war and the light which that work has thrown upon the area of existing coalfields and the possible development of new ones.

(2) Those minerals which occur in such quantity that the whole of the country's resources are never likely to be required. Into this category come chalk and limestone required for the manufacture of cement, clay for bricks and tiles, slate for roofing slates, sand and gravel for building and other purposes. Where the resources of the mineral are in excess of national requirements there is the possibility of exercising control over the location of the mines or quarries and of the industrial establishments using the raw material. Whether the manufacture of cement, which must be regarded to some extent at least as a 'dirty' and therefore noxious industry, should be concentrated in one or two parts of the country, or whether there should be a spread so that each major region of the country has its own local supplies is a matter to be decided on economic considerations, but the basic data regarding the occurrence of the raw materials must be supplied by the geologist. It is surprising how little is known in some parts of the country of the distribution and character of gravels and sands, yet it is the removal of gravel which has caused the devastation of very large areas indeed of otherwise valuable land. This has not only affected amenity in many parts of the country, but has robbed the nation of large tracts of valuable food-producing farmland. The restoration of such land would seem obviously to be a national duty. How it should be carried out is not a matter primarily for the geologist, but there is need for a closer collaboration between the geologist and the technician regarding the character of many of the deposits. A geologist can map gravel deposits, but the building technicians will say that some types of gravel are completely unsuited for such purposes as the making of concrete, and there is need of both a geological map and what might be called a 'gravel classification' map. The same, of course, applies to different qualities of limestone, building stone and so on.

The field of work here proposed for the geologist illustrates very well the general position governing the relationship between many branches of science and the work of the town or country planner. The latter requires a presentation of data in a particular form in which it may not have been collected previously by the scientist for his own or other purposes, and may therefore need a new and sympathetic approach on the part of the scientist. Another example of the same sort within the sphere of the geologist is in regard to the mapping of drift deposits. Despite the hundred years' work of the Geological Survey and the investigations of innumerable amateur and professional workers, no drift map of any sort whatsoever is available for the whole of Britain or even for the whole of England. Drift deposits have never been mapped over large and important parts of the Midlands. This hinders the work of the soil scientist, it restricts our knowledge of hydrology, and is a most serious gap in the basic information required by the land planner.

In this connexion reference should be made to the work of the Research Officers and the Central Maps Office of the Ministry of Town and Country Planning. The latter, in conjunction with the Ordnance Survey, has been preparing for publication a series of maps on the scale of 1 : 625,000 (approximately 10 miles to the inch) which show data basic to the work of national planning. Although these maps have been considered in relationship to their immediate usefulness as base maps, it is interesting to note the great use which was made of the Report of the National Maps Committee of the British Association. It will be recalled that the National Maps Committee was set up some years before the war at the instance of several interested Sections, and that it drew up, with the aid of technical sub-committees, a detailed list of maps desirable for a National Atlas. Many of the maps envisaged but not then in existence have now been prepared by the Ministry of Town and Country Planning, and it might be argued that the country is now being provided with a National Atlas. The sheets are, in fact, rather large to be regarded as an atlas, but it may be possible in due course to issue others on half the scale which would form an atlas of manageable size.

A general map of solid geology is in preparation by the Geological Survey and a promise has been made that at least a tentative map should be prepared showing drift deposits, but the great problem of the restoration of land worked over for gravel has necessitated specific surveys of gravel deposits being carried out in many areas. Everywhere there is need for further survey.

It will be noted that a considerable part of the normal work of investigation of the geologist has little direct bearing on the work of planning. For example, the whole investigation of geological age of the solid rocks is relatively unimportant. It is their lithology and disposition which have the greatest significance.

(b) *The Contribution of the Geomorphologist*

It is perhaps unnecessary to stress the extreme importance in planning of the relief of the ground. In general this is portrayed on the published maps of the Ordnance Survey and it is easy to pick out on a national scale those areas where the extreme elevation of the land renders economic development impossible or difficult. On a smaller scale the wise town planner will base his work on detailed maps with contours at every 5 or 10 feet and on accurate scale models of the terrain where development is proposed. Such models have been a feature of many of the recent exhibitions of town plans. One disturbing feature of modern trends is the way in which local authorities hesitate to choose in building development anything but flat or almost flat land. 'A good building site' has almost come to mean a site which is flat and well drained. It is admittedly much more difficult to prepare a town plan for land which is varied in its relief, but surely it can be urged that the resulting town can and probably would be far more attractive than one laid out on a flat plain. The interminable stretches of suburban development carried out between the wars on the gravel terraces of south Middlesex not only destroyed some of the country's finest market-gardening land, but resulted in suburbs which, if not to be described as dreary and monotonous, do tend to lack the attraction of some of the older towns of the countryside built by our ancestors on relatively hilly country. One may think of the difficult site occupied by the city of Bath, which would probably have been condemned by a modern town planner as quite impracticable as a town site.

There is probably much which can be contributed by the comparatively young science of geomorphology in the work of interpreting and explaining the meaning of slight differences in relief, and in conjunction with the geologist the geomorphologist has a contribution to make in stressing the relative stability of slopes as building sites. The detailed application of geomorphological studies to town and country planning is virtually an untouched field, but one full of possibilities of the utmost importance.

(c) *The Contribution of the Hydrologist*

Never was there a time when the chaotic state of our knowledge regarding actual and potential water supplies, both underground and surface, was so apparent as at the present time. Pioneers like W. N. McLean have long urged at meetings of the British Association and elsewhere the need for systematic river gauging in this country. We are in the fantastic position of having a rainfall which is everywhere adequate, often excessive, involving extensive drainage works to secure the adequate drainage of agricultural land, and yet the majority of rural districts and probably at least 75 per cent. of farms are suffering from a shortage of water, often so acute as to render adequate farming, notably dairy farming, virtually impossible. Combined with this there is the undignified scramble of the large urban authorities to secure the rights of distant water supplies and the spectacle of criss-crossing main aqueducts passing over land crying out for further water. The position at the present day is well exemplified by the city of Leicester and Leicestershire. The city has secured by agreement with three other powerful cities a moiety of the water from the new Ladybower Reservoir in the Derwent Valley, but to safeguard future supplies wishes to create a reservoir and submerge some valuable land in the upper Manifold Valley of Staffordshire, bringing the water by aqueduct through country, valuable farming land, where there is often an acute shortage.

Fortunate farmers with sufficient capital resources can often tap underground supplies far in excess of their needs, whilst their less fortunate neighbours may rely on a single well, liable to go completely dry in some seasons. Something approaching a complete hydrological survey is a contribution which should be made from the scientific angle, and is a great need of the moment.

(d) *The Contribution of the Pedologist*

The science of the study of the soil *qua* soil is, in this country, relatively modern. The Soil Survey of England and Wales is under the auspices of the Ministry of Agriculture and Fisheries and is directed by Professor G. W. Robinson of the University of Wales, Bangor, aided by a small staff of soil surveyors, and great progress has been made both with detailed mapping of soil series on the 6-inch scale and also of rapid reconnaissance mapping on the ½-inch and 1-inch scales in the last few years, but it is still true that over large parts of the country the only soil maps available are the extremely generalized and sketchy soil texture maps which illustrate the reports made to the Board of Agriculture between 1793 and 1800. The modern method of mapping soil series, combined with an indication of drainage conditions and of deep and shallow facies, gives the expert the basic information, but it needs to be interpreted for the town and country planner. Whereas the study of existing land use gives the answer regarding good and poor land, it is the soil scientist who should be able to place the emphasis on soils which are good potentially as well as

those which are good as a result of basic character and existing management. Herein lies the danger. In translating results for the use of the planner the soil scientist may easily go too far by arranging his soils into good, medium and poor from the agricultural point of view, but so many other factors enter into their utilisation that this classification based on soil qualities is not necessarily the answer to the problem—what is good agricultural land and what is poor? The relationship has been thrashed out between the two points of view and an agreed simple classification was drawn up and is now used by the Ministries of Agriculture and Town and Country Planning and is shown on the recently published Land Classification Map issued as part of the national series on the 1 : 625,000 scale. The pioneer work here was done by the Land Utilisation Survey and the investigation of the difficulties is to the credit of the unofficial research group known as the West Midland Group, under the chairmanship of Dr. R. E. Priestley, Vice-Chancellor of the University of Birmingham.

(e) *The Contribution of the Climatologist and Meteorologist*

There is an enormous field at present scarcely touched in the application of meteorological and climatological studies to the whole work of planning. Rather naturally the great strides which have been made in meteorology in recent years have been in large measure connected with the structure of the atmosphere and an interpretation of the behaviour of masses of air. Forecasting has been of tremendous importance to the Air Force, the Navy, as well as to the Army and Combined Operations. New and special investigations have been required. Now it is the application to entirely different matters which calls for attention and for considerable research, often involving a novel point of view.

First, from the broad point of view of the country as a whole, there is insufficient knowledge of the distribution of fog and mist, obviously important in the development of air transport, especially when small private planes and taxi planes are likely to become increasingly used. In the same way the incidence and duration of snow cover need further study as affecting the liability of roads in certain areas to be blocked by snow, and thus the general question of road haulage and consequently the suitability of whole areas for industrial development. As certain industries come to rely more and more on road transport, their isolation through snow covered roads becomes of ever greater importance.

During the war it has been recognised by the differential allocation of coal for the domestic ration that there are differences in winter temperatures between the north and south of Britain. These climatic conditions are sufficient to render necessary different building techniques in different parts of the country. If central heating becomes general, and especially if district heating is adopted, the differences between the colder and drier east and the damper, milder west are likely to be even more significant than differences between north and south, and it would seem that investigations into cumulative temperatures and their significance are required.

It is perhaps unnecessary to stress the importance of the temperature factor in agriculture. The phenological investigations carried out for many years past are based on the flowering dates of a number of common wild flowers, but there is need for a refinement in this method, using plants of economic importance and dealing with their vegetative growth as well as their flowering periods. There are undoubtedly parts of the country, e.g. Pembrokeshire, capable of being as suitable for early vegetables as areas already so used in the south-west, but full investigations are lacking.

There is an enormous field awaiting detailed work in micro-climatology. Every gardener knows the difference between one part of his garden and another—the value of a sheltered wall, or the danger of a draughty corner—but extraordinarily little investigation of really scientific character has been carried out on the meaning of these small differences. It is interesting to note that standard observations in the Stevenson Screen are made with instruments placed at four feet from the ground and well removed from the interference of buildings. Four feet off the ground is perhaps the least important height which could be chosen from the point of view of agriculture. Few annuals ever reach this height. What matters to them is the variation of temperature in the soil and a few inches from its surface. On the other hand, such things as frost damage to fruit only become serious at a height of *more* than four feet from the ground. Pioneer work in pure observation such as that carried out by Mr. Raymond Bush is of extreme importance and offers a field for many amateur observers. The national stake involved is enormous. There seems to be good ground for believing that at least three-quarters of all the orchards in this country are wrongly sited in relationship to frost liability and air drainage and that the whole great economic problem created by wide fluctuations in fruit-yields from year to year could be avoided by correct siting of orchards.

Although it is known that atmospheric temperatures vary with both the texture and

colour of the soil, the presence or absence of a grass cover, detailed investigations are few. The town and country planner is working at present in the dark. Often the only information of use to him is local gossip or belief that certain slopes or certain situations afford valuable sites for orchards, market gardens, etc. He is faced with the immediate problem as to whether the local climate is such that the land concerned should be kept for specialised agricultural production, or whether, if it is needed for housing development, other land is equally suitable. There seems no doubt that some of the valleys in the south-west, with free air drainage to tidal water, have a national importance which puts them in the highest category of land which should be kept for agricultural production. On the other hand, in how many cases should an orchard, just because it is there, be kept rather than be developed, if needed, for building when the possibility is that it may be situated in a dangerous frost hollow? Is there any justification on this basis for seeking to keep *any* of the orchard lands of Middlesex?

There is no doubt, too, from the planner's point of view, that meteorologists have tended to be obsessed with the importance of averages, whereas it is the unusual, such as spells of abnormally low temperatures, which is of greater significance.

The whole significance of aspect is indeed little known. A farmer will often indicate that one or more of his fields is three weeks earlier than others and that the success of his farm depends upon balancing not only the different types of land but of land with slightly different, but nevertheless important, aspects.

Aspect is also important to human beings. The altitude of the sun at noon in midwinter in Britain is only between 6° and 16° above the horizon. This affects the spacing and height of buildings. Is it possible to measure scientifically the importance to health of being 'on the sunny side of the street?' This concerns especially town planning in valleys and there is need for much more scientific investigation, developing the work of Dr. Alice Garnett.

(f) *The Contribution of the Biologist*

Not only is man an animal—and hence the whole field of social biology is involved in planning—but the environment within which he lives is essentially a living environment. Thus the planner is dealing the whole time with living things and for that reason is very liable to make fundamental errors. The town and country planner is often by training an architect and the bulk of his training has been in the drawing office. From the design and planning of individual buildings he graduates to the design of groups of buildings, and so to town plans. It must be regarded as one of the deficiencies of such a training that he is brought so little into contact with living things and with the field environment within which his paper plans will take material form.

One result of this is seen in the provision so frequently made in town plans for the 'preservation' of commons or tracts of open land. It is simply not realised that the commons as well as the open farmland owe their attractive character to the use which is or has been made of them. It is certainly not realised that the grassy meadow so attractive by the side of the wandering stream is there because it has been used by grazing cattle or regularly mown for hay. In a town-planning scheme it may be marked as 'permanent open space, to be acquired by the Urban Authority.' Innumerable examples could be quoted where such a policy has been carried into effect and within a very few years the once attractive meadow has become a wilderness of thorn and weed. Thus the constant guidance of the ecologist is needed, and this applies also in larger spheres.

It will certainly be needed in the management of National Parks, whilst a beginning has only recently been made in the application of ecological principles to forestry management. Trial and error in afforestation involves much time. We do not yet know whether pure stands of a single species, so rarely seen in nature, can be satisfactory when planted by man. Evidence is accumulating that they are not. The constant and most unfortunate wrangling between the so-called amenity interests and commercial forestry must be eliminated, and it is gradually becoming clear that the rectangular blocks of pure conifers, to which the greatest objections are raised by those whose concern is primarily the preservation of the beauty of the countryside, are in fact biologically undesirable.

The biologist has another most important contribution to make in the study of the environment, for the maintenance of the balance of animal and vegetable life is so obviously easily upset in town planning schemes. Social biology and demography are so intimately connected with the whole work of the town and country planner that they must be regarded as absolutely fundamental. Yet only too often even the well-known and obvious truths are ignored. For example, the general population trends as regards overall numbers are known and would point at once to the absurdity of towns planning for three, four, five or even six times their present population.

The age-composition of the population and especially the size of the family are of fundamental importance, not only in the size and type of dwelling to be constructed but in the provision which must be made in any new housing development for schools and playing fields, *vis-à-vis* homes for old people and recreational facilities for them. Too often our building schemes are based upon the experience of a past generation, when the age-composition of the population was entirely different from what it is at present and will be in the future.

Investigations of the incidence of disease are important, though they tend mainly to prove the unsatisfactory nature of crowded living conditions, already known to be undesirable on other grounds. They emphasize the significance of the desire for more space and less crowding, they give a reason for encouraging the development of garden suburbs and garden cities. Unfortunately, however, some of the lessons have tended to become crystallized in too rigid a form. As an example of this, the insistence on an eight-foot ceiling in a country cottage, which is properly ventilated and has an abundance of fresh air, would seem to be not only unnecessary but positively harmful in giving rise to rooms which are too small for their height and to houses which are as æsthetically unpleasant as they are biologically unnecessary in their construction.

Remarkable as it may seem, the establishment of a society (the Nutrition Society) in this country for the special study of nutrition is a wartime phenomenon. The proper nutrition of the people has of course been taken as the basis of our wartime rationing and we are apt to forget that in the pre-war years some 30 per cent. of the people of this country were suffering from preventable mal-nutritional diseases. This state of affairs must never be allowed to occur again. The whole planning of our countryside should be based on nutritional needs of the population. The farmer should be given security of tenure, a guaranteed market, and prices fixed in advance which will enable and encourage him to produce that range of agricultural products which will secure both the proper balanced use of the land—in other words good husbandry —and will enable the housewife, when rationing is no more, to buy those foods needed for the health of the family. Meat, milk, eggs, butter, fresh fruit, a wide range of vegetables—indeed all the so-called protective foods—are those which should be within the range of even the lowest income groups. Deliberate State planning is undoubtedly necessary to secure this result, but if subsidies are needed they must be regarded as subsidies to the consumer rather than as subsidies to the farmer as producer, and surely it is to the national advantage to spend if need be large sums on a National Health Service of Preventive Medicine—in other words proper nutrition—rather than equivalent sums on hospitals and curative medicine when the damage has already been done.

V. The Application of Science in Town and Country Planning

In conclusion, what lessons may be drawn from this survey? The first is that town and country planning, whether on a national or local scale, can only be successful if it is founded on sound scientific principles. In the second place there are very many factors involved, and there is a great danger that the representative of any one science may, because he realises the importance and significance of his own studies, be unsympathetic to the importance of the others. There is thus a very important field for those scientifically trained who are capable of co-ordinating and presenting in a form suitable for direct use and interpretation by the planner of scientific results. In so far as the incidence of factors must be equated and evaluated, there is important work for the statistician. There is obviously an important field, too, for the economist, but the economist is also concerned with economic and financial planning, and there is danger that financial consideration of our monetary position may assume a disproportionate place in his analysis. So many of the scientific factors involved are, in fact, imponderables. This is well seen in the case of food. One fully recognises the importance in our economic system of cheap food. Unfortunately we have at present no means of assessing in monetary terms differences, it may be even slight, in nutritive value: for example between fresh salad vegetables and the same which have been kept for a number of days or weeks in cold storage.

Of especial value in this work of co-ordinating scientific results is the geographer. His special field is a study of distributions and space relationships and their delineation in cartographical form, and he is thus best qualified by his training to prepare the maps which are so clearly needed as a basis for the planner's work, and at the same time is especially equipped to undertake field surveys and the analysis of the results. It is not surprising, therefore, that the lead in this work in recent years has been taken by the University-trained geographers of the country.

INTERNATIONAL SCIENTIFIC CO-OPERATION

An article on the activities of the International Council of Scientific Unions, prepared by Prof. F. J. M. Stratton, D.S.O., General Secretary, I.C.S.U., and published by request of the Executive Committee of that body.

THE gradual easing of restriction on travel and on the general release of scientific discoveries has made it practicable once more to arrange international meetings of men of science. The general Assembly of the International Council of Scientific Unions will meet in London on July 22–24, 1946. Meanwhile its Executive Committee has held a meeting in London attended by representatives of most of the International Unions adhering to the Council.

In welcoming the Committee at its opening session Dr. A. V. Hill, C.H., Foreign Secretary of the Royal Society, pointed out that science in its own interest must remain an international concern and that the future of civilisation itself depended upon the close co-operation of scientific men throughout the world. Taking as an example the field of medicine and the high ethical principles which had been developed therein he emphasised the need for a common standard of ethical behaviour in science. ' In standards of truthfulness and integrity, in readiness to co-operate with other scientists of good will everywhere, and in refusal to use the common knowledge, prestige and power of science for base, harmful and selfish ends, scientists should feel themselves bound by an honourable and unbreakable obligation.'

The heavy toll of recent years on those prominent in the field of international science was revealed by the list of members of the Committee who had died since its last meeting : Il Marchese Marconi and Baron Joji Sakurai, Vice-Presidents ; Sir Arthur Eddington, President of the International Astronomical Union ; Prof. Nicola Parravano, President of the International Union of Chemistry ; Sir Albert Seward, President of the International Union of Biology ; Dr. Philippson, General Secretary of the International Union of Physics, and General Bourgeois, former Vice-President, representing the International Union of Geography.

The President of the Council, Prof. C. Fabry, had been compelled to resign on account of ill-health (he has since died) and Dr. H. R. Kruyt was elected President, Dr. Elmer D. Merrill being elected Vice-President in his place.

The International Council, or rather its predecessor the International Research Council, was created after the first World War, and took as its main task the creation of the various international scientific unions. In the early days the council exercised a certain amount of control over these unions in such questions as membership and finances. As the individual unions became established and strong this control proved irksome and a change took place in the relative positions of the Council and the Unions, largely the work of the then General Secretary of the Council, the late Sir Henry Lyons.[1] Now it would be fairer to say that the Unions control the Council, the majority of the members of the Executive Committee being the representatives of the Unions. The Officers and two members of the Executive Committee only are appointed by the General Assembly at which the national adhering organisations have a preponderating vote.

The International Unions meet in General Assembly as a rule once in three years for discussions on the field of knowledge lying within their purview ; by means of numerous committees of specialists work is carried on between the meetings and is reported on and discussed at the meetings of the General Assembly. Ninety-two such committees have been reported as working in the various International Unions, their activities covering a very wide field of knowledge. Each Union also appoints at its General Assembly a small bureau of officers who are able to answer for the Union as a whole between meetings. Some of these have been badly broken up during the war years and are only now being rebuilt.

In addition to the International Unions there are in existence a number of International Congresses which meet from time to time in different countries but have no continuity of active existence between meetings. Broadly speaking, it would be safe to say that those who have been actively concerned with these Congresses and have pleasant recollections of their scientific discussions and fellowship do not desire to change them into International Unions. The weakness of their position, however, is the lack of a body between meetings that can answer for the subject covered by the Congress, and can nominate the most suitable members for co-operation with Unions desiring their help. Borderline subjects needing international study are catered for by joint commissions between the various Unions. It would be a help if an International Congress would appoint a bureau to function between meetings to which the various requests for assistance or advice could be addressed. This is done in some cases already. In other cases Union and Congress both exist. The General Assembly of the Union meets at the same place as the Congress and within a day or two of the Congress meeting. Elasticity of organisation is desirable to meet the different needs and outlook of workers in different fields.

Joint commissions of the Unions have been active for over twenty years in some cases, for instance the joint commissions on latitude variation, on the determination of longitudes by wireless, and on the Bureau de l'heure, in which both the Unions of Astronomy and of Geodesy and Geophysics are concerned. Some joint commissions are only planned as yet, e.g. a commission on ionospheric research, which it is hoped to set up in due course with members from the Unions of Astronomy, Geodesy and Geophysics, Radio-Science and Physics. Other joint commissions proposed at the recent executive committee of the Council are on Oceanography (Biology and

[1] An article on ' The International Research Council (later the International Council of Scientific Unions),' by Sir Henry Lyons, was published in *The Advancement of Science*, vol. II, no. 6, p. 178 (1942).

Geodesy and Geophysics), Physico-Chemical Constants (Physics and Chemistry), Viscosity (Chemistry, Biology, Geodesy and Geophysics). In the work of this committee it is hoped that means will be found to secure the co-operation of the International Congress of Applied Mechanics.

In addition to joint commissions between the Unions, which the Council may help to arrange, the Council also appoints committees of its own such as the Committee on Solar and Terrestrial Relationship, in which are members from the Unions of Astronomy and Geodesy and Geophysics. Another committee of the Council is one on Science and Social Relations (C.S.S.R.) appointed in 1937 to survey the most important results obtained and the directions of progress that are opening and of points of view brought forward in the physical, chemical and biological sciences with reference to their inter-connection, the development of the scientific picture of the world and their practical application in the life of the community. In response to the inspiring and untiring energy of Prof. J. M. Burgers, Secretary of this committee, reports were being received from countries and Unions in the years 1938–9 in readiness for collation and publication when the outbreak of war interrupted the work. Some of these reports, such as one on the Social Aspects of Science in Estonia, are now only of historical interest, and the Committee has now been asked to prepare a survey of the published views of scientific bodies on the problems now arising in connection with researches into such matters as nuclear physics and drugs. Such a survey may enable the Council to make a reasoned pronouncement, supported by the full weight of international science, on the ethical problems which face scientific men in particular to-day—thus accepting the challenge offered by Dr. Hill to the Executive Committee in his address of welcome at their recent meeting. A valuable contribution to the work of the C.S.S.R. will be provided by the annual reports on the work of the various Unions which the Council hopes to receive in future and to distribute widely.

The Council is linked by a convention to the International Organisation for Intellectual Co-operation of the League of Nations ; the convention defines the separate spheres of action of the two bodies and the various ways in which each can help the other. While the fate of the International Organisation of the League of Nations is uncertain at present, there has come into existence the United Nations Educational, Scientific and Cultural Organisation (U.N.E.S.C.O.). At the recent conference at which U.N.E.S.C.O. was formed a resolution was adopted, on the proposal of the delegation from the United States, asking the preparatory commission to invite its executive committee to examine with the International Council of Scientific Unions such methods of collaboration as might be practicable to strengthen the programmes of the two organisations within the limits of their joint concern ; the Executive Committee of the Council has appointed a committee to consult with representatives of U.N.E.S.C.O., and it is hoped that much may arise from their discussion to the mutual advantages of both bodies. The clause introducing this resolution may well be taken as defining the task now facing the International Council of Scientific Unions :

' Il est urgent de reconstituer et de développer les moyens permettant aux savants de tous les pays d'échanger des renseignements et de travailler en commun au développement de la science et à son utilisation au service de l'humanité.'

STATUTES AND REGULATIONS OF THE ASSOCIATION: REVISION OF 1945

STATUTES

CHAPTER I

Objects and Constitution

Objects.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress.

The Association contemplates no invasion of the ground occupied by other Institutions.

Constitution.

2. The Association shall consist of Members, Honorary Members, and Associates.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

Meetings.

3. The Association shall hold an Annual Meeting, and such other meetings as the General Committee may appoint. The venue of each Annual Meeting shall be determined by the General Committee not less than two years in advance, and may be any place or places within the British Commonwealth and Empire or elsewhere as the General Committee shall determine. The arrangements for these meetings shall be entrusted to the Officers of the Association.

Divisional Conferences.

4. It shall be competent for the Committee of the Division for the Social and International Relations of Science, constituted as hereinafter provided, to arrange Conferences on such subjects, and at such times and places, as the Council shall approve.

CHAPTER II

The General Committee

Constitution.

1. The General Committee shall be constituted of the following persons:—

(i) Past and present Members of the Council.
(ii) Past and present Presidents of the Sections, and Recorders of Sections on retirement.
(iii) Vice-Presidents and Secretaries of the Sections, and Officers of the Division for the Social and International Relations of Science, during their terms of office.
(iv) Delegates of Scientific Societies present at any Annual Meeting and invited by the Council to join the General Committee at such meeting.
(v) Persons other than those qualified as stated above, whose services to science are considered by the Council to render their membership of the Committee desirable.

Admission.

2. The Council may confirm in continued membership of the Committee any person who shall have qualified as provided in clauses (iii) and (iv) of paragraph 1 preceding.

No person other than life Members of the Association or Members maintaining annual subscriptions thereto shall be members of the General Committee; and no person who shall have intermitted attendance at three or more consecutive Meetings of the Association shall be entitled to continue in membership of the General Committee, unless invited to do so by the Council.

The decision of the Council on the qualifications and claims of any Member of the Association to be included in the General Committee shall be final.

Meetings. 3. The General Committee shall meet during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall—

(i) Receive and consider the Reports of the Council and the General Treasurer.

(ii) Determine the place of the Annual Meeting not less than two years in advance.

(iii) Determine the date of the next Annual Meeting.

(iv) Elect the President of the Association, the General Officers, Ordinary Members of the Council, and Auditors.

(v) Exercise all other such functions as by these Statutes are assigned to it as the governing body of the Association.

CHAPTER III

The Council

Constitution. 1. The Council shall consist of *ex officio* Members, and of Ordinary Members elected annually by the General Committee as hereinafter provided.

(i) The *ex officio* Members are—Past Presidents of the Association, the President for the year, the President and the Vice-Presidents for the ensuing Annual Meeting, past and present General Treasurers and General Secretaries, and the Local Treasurers and Local Secretaries for the Annual Meetings immediately past and ensuing.

(ii) The Ordinary Members of the Council shall be so nominated and elected as to include at least two representatives of each Section of the Association, provided that the total number of Ordinary Members shall not exceed thirty. Of these, five shall retire each year, and shall not be eligible for re-election during the ensuing year, as hereinafter provided.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt their Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

The Council shall elect Vice-Presidents of the Association for each Annual Meeting.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

Elections. 3. Election to the Council shall take place at the same time as that of the Officers of the Association.

At each Annual Election, five of the Ordinary Members of the Council who shall have served for the longest consecutive period shall be ineligible for re-election in the ensuing year, provided that the Council, in making their nominations, may substitute for not more than three such Members the names of Members who have attended the least number of meetings during the past year.

The Council shall submit to the General Committee, in their Annual

Report, the names of Members of the Association not exceeding twenty-eight in number, whom they recommend for election as Members of Council.

Two Members shall be elected by the General Committee without nomination by the Council ; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place. Any Member of the General Committee may propose another Member thereof for election as one of these two Members of Council, and, if only two are so proposed, they shall be declared elected ; but, if more than two are so proposed, the election shall be by show of hands, unless five Members at least, present at the meeting of the General Committee, require it to be by ballot.

CHAPTER IV

The President, General Officers, and Staff

President.

1. The President shall assume office on the first day of January next following the Annual Meeting at which he is appointed. He shall deliver a Presidential Address at the Annual Meeting during his year of office, and shall vacate his office on the thirty-first day of December next following that meeting.

General Officers.

2. The General Officers of the Association are the General Treasurer and the General Secretaries.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council ; and they shall report such action to the Council at the next meeting.

General Treasurer.

3. The General Treasurer shall be responsible to the Council and the General Committee for the financial affairs of the Association.

General Secretaries.

4. The General Secretaries shall control the general organisation and administration and shall be responsible to the Council and the General Committee for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

Secretary.

5. The Secretary of the Association shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Secretary shall be charged, subject as aforesaid : (i) with the general organising and editorial work, and with the administrative business of the Association ; (ii) with the control and direction of the Office and of all persons therein employed ; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, Committees of the Council, and the General Committee.

CHAPTER V

The Annual Meetings

Local Committees.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number.

Local Officers.

2. The Council shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

Functions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections.

Public Occasions.

4. The Council, in consultation with the Local Executive Committee of the Association for the Annual Meeting, may provide evening or other lectures, demonstrations, and exhibitions during the meeting, to which persons not Members or Associates shall be admitted free ; and the Council shall appoint speakers for these purposes, having regard to the scientific and educational needs and interests of the place of meeting and its neighbourhood.

CHAPTER VI

The Sections

1. Sections of the Association shall be constituted from time to time by the General Committee for the transaction of scientific work.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Sectional Committees.

3. The arrangement of the Sectional programme and other work of each Section shall be conducted by a Sectional Committee consisting of the Officers of the Section during their term of office, past Presidents of the Section, the Recorder for one year after the completion of his term of office, and not more than six other Members of the Association. Sectional Committees shall be appointed by the Council, provided that during an Annual Meeting a Committee may fill vacancies in its own body caused by the absence of any of its Members from the Meeting, and may also co-opt for the period of the Meeting such other Members present thereat as may help to meet the requirements of the work of the Section.

Executive Functions of President and Recorder.

4. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee ; and they shall report such action to the Sectional Committee at its next meeting.

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise.

The Recorder shall be responsible for the punctual transmission, to the Secretary of the Association, of the programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee.

Procedure of Sectional Committees.

5. Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting ; to supervise the programme of the Section, to co-opt members, to take into consideration any suggestion for the advancement of Science that may be offered by any Member of the Association or may arise out of the proceedings of the Section, and to nominate, if the Committee so desires, Sectional Officers and members of the Committee for the ensuing year, for the consideration of the Council.

Papers.

6. No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes.

Recommendations.

7. It shall be within the competence of any Sectional Committee to review recommendations adopted at preceding Annual Meetings as published in Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed ; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required : to make recommendations and nominate individuals or research committees to whom the preparation of such reports, or the task of research may be entrusted, discriminating as to whether, and in what respects, these

objects may be usefully advanced by the appropriation of money from the funds of the Association, by reference to local authorities, public institutions, or Departments of His Majesty's Government, or otherwise. The appointment of such research committees shall be made in accordance with the provisions of Chapter VIII.

8. Recommendations arising out of the proceedings of any Section, provided that they have received the sanction of the Sectional Committee, shall be referred to the Council for consideration, and, if found desirable, for action.

CHAPTER VII

Division for the Social and International Relations of Science

Purposes.

1. There shall be within the Association a Division for the Social and International Relations of Science, with the purposes of furthering the objective study of the social relations of Science, and of extending and maintaining international interests in this field.

Committee.

2. The affairs of the Division shall be conducted by a Committee, which shall be appointed annually by the Council. The Council shall also appoint such officers as the working of the Division may require.

The President and General Officers of the Association shall be *ex-officio* members of the Committee.

Functions.

3. The functions of the Committee shall be :—

(i) To arrange Divisional Conferences both at the time and place of the Annual Meeting of the Association, and elsewhere at other times as invited or otherwise arranged, and to appoint chairmen and speakers at such Conferences.

(ii) To furnish material for the information of the public.

(iii) To co-ordinate work dealing with the social relations of Science both at home and abroad.

(iv) To maintain close relations with the Sections of the Association and their Committees.

(v) To act in a consultative capacity and supply information, and to that end to establish relations with Societies in correspondence with the Association and with other organisations and persons engaged in practical administration.

(vi) To set up sub-committees for executive purposes, research, inquiry, or co-ordination. If any such sub-committee shall require a grant of money for its work, the Committee shall be empowered to apply for such grant to the Council in accordance with the procedure relating to Research Committees provided for in Chapter VIII.

(vii) To make recommendations and reports to the Council as deemed desirable, and to report annually through the Council to the General Committee.

CHAPTER VIII

Research Committees

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section ; and, if such proposal be approved, it shall be referred to the Council.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association.

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and appoint Members to serve on it, not more in number than is consistent with its

efficient working; and shall nominate a Chairman and a Secretary. Research Committees shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed, and may in the meantime present a Report through a Sectional Organising Committee to the Council. Interim Reports whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Council.

Grants.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for the sum granted or such portion thereof as from time to time may be required.

It shall be competent for the Council to make grants for research to individuals from such of the Association's funds as permits of such grants under their terms.

Grants of money sanctioned at or after any Annual Meeting expire at such date preceding the next Annual Meeting as the Council, or the General Officers duly authorised by them, shall appoint. The General Treasurer is not authorised, after such date, to allow any claims on account of such grants.

No Research Committee or individual shall receive grants from the Association over a period or periods exceeding five years in aggregate, either from the general funds of the Association, or from any special fund unless its conditions permit the contrary.

A Research Committee or individual, whether or not in receipt of a grant, shall not seek to raise money, in the name or ostensibly under the auspices of the Association, without the special permission of the Council.

CHAPTER IX

Corresponding Societies

Admission.

1. It shall be competent for the Council to admit to correspondence with the Association any Society formed for the purposes of encouraging the study of Science or any department thereof which is within the sphere of the Association.

Delegates.

2. Each Corresponding Society shall have the right to appoint a Delegate or Delegates not exceeding six in number, to attend the Annual Meetings of the Association. Such Delegates shall be or become Members of the Association.

Committee.

3. A Corresponding Societies Committee shall be appointed annually by the Council for the purpose of keeping themselves generally informed of the work of the Corresponding Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable.

Conference of Delegates.

4. It shall be competent for the Council, on the recommendation of the Corresponding Societies Committee, to summon a Conference of Delegates of Corresponding Societies and to appoint a President and other officers thereof, to meet during the Annual Meeting for the consideration of matters of common interest to the Association and the Societies or any of them, and to make recommendations to the Council under conditions similar to those provided for the Sections of the Association. Any such recommendation dealing specifically with a particular department of Science shall be referred to the Sectional Committee concerned before reference to the Council.

5. On any question carried to a division in the Conference of Delegates, no Society shall exercise more than one vote through its Delegates. Voting.

CHAPTER X

Finance

1. The General Treasurer, or his representative, shall receive and acknowledge all sums of money paid to the Association. He shall prepare and submit to the Council and the General Committee a balance-sheet of the funds of the Association completed to the close of the financial year, and shall submit at any meeting of the Council an interim statement of his Account if so requested. Financial Statements.

2. The Accounts of the Association shall be audited annually by Auditors appointed by the General Committee. Audit.

3. The General Treasurer shall make all ordinary payments authorised by the Council or by the General Committee. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and, with the authority of the Council, to invest on behalf of the Association part or all of the balance standing at any time to the credit of the Association in the books of the Association's bankers, in such investments as may be authorised for the investment of trust funds. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

6. No gift, bonus, dividend, or division in money shall be made out of the funds of the Association, to or between any of its Members. *Caveat.*

CHAPTER XI

Publication and Copyright

1. Reports of the Association shall be published in its journal 'The Advancement of Science' or otherwise as the Council shall direct; and the publication price of, and subscription rates for, reports shall be determined by the Council from time to time, subject to any statutory rights of libraries, or to other considerations in the Council's discretion. Publication.

2. The copyright of all addresses, lectures, and papers whatsoever published by the Association, and of reports of Research Committees appointed by the General Committee or the Council, shall be vested in the Association. It shall be competent for the Council to assign the copyright of any address, lecture, paper or report. Copyright.

CHAPTER XII

Admission and Privileges of Members and Associates

1. No technical qualification shall be required on the part of an applicant for admission as a Member or Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

The Council shall also have power to refuse any application for membership or associateship.

Every person admitted as a Member or Associate shall conform to the Statutes and Regulations of the Association, and for any infringement thereof shall be liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. Obligations.

If it shall appear to the Council that it is not desirable that a person shall continue to be a Member or Associate of the Association, the Council shall direct the General Secretaries to ascertain whether that person is willing to resign his membership or associateship. Exclusion.

If that person do not, within a time to be fixed by the Council, either resign or appeal in writing to the General Committee, the Council may declare such person to be no longer a Member or Associate. Upon the appeal, the General Committee may make the like declaration by a majority of two-thirds of those present and voting.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency affecting any Member or Associate or applicant for membership or associateship which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

Conditions and Privileges of Members and Associates.

2. The following subscription rates shall be payable to the Association :—

(i) The subscription for Membership for one year shall be two guineas. A Member shall be entitled to attend meetings during the year for which such payment is tendered, and to receive such publications of the Association as the Council shall from time to time determine; and shall be eligible to any office of the Association.

(ii) A life composition of twenty-five guineas shall be payable at any time in lieu of future annual subscriptions.

(iii) The subscription for Associateship for one year shall be one guinea. An Associate shall be entitled either to attend meetings during the year for which such payment is tendered, or to receive such publications of the Association as the Council shall from time to time determine; and shall not be eligible to office in the Association.

(iv) Students of undergraduate or similar standing, in universities or in any educational institution recognised by the Local Executive Committee or the General Officers of the Association, may obtain Students' Tickets for the Annual Meeting on payment of 10*s*. Holders of such tickets shall not be entitled to any privilege beyond attendance at the Annual Meeting.

(v) Any British corporate body approved by the Council shall, on an annual payment not less than ten guineas, be entitled to appoint representatives not exceeding five in number to attend the Annual Meeting, and to receive such publications of the Association as the Council shall from time to time determine.

Honorary Members.

3. Honorary Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Annual subscriptions shall become due on the first day of April in every year and shall be in respect of the financial year ending on the thirty-first day of March next following the actual date of payment in each case, provided that a Member shall not by this be prevented from making good arrears of subscription nor a new Member from directing at the time of payment that his first subscription shall be appropriated to the first complete financial year next following.

Arrears.

5. No Annual Member or Associate rejoining after intermission shall be liable to be called upon for arrears.

CHAPTER XIII

Amendments and New Statutes

Any alteration of or addition to any of the Statutes, and any new Statutes, which may be proposed by the Council or individual Members, shall receive the approval of the General Committee, before being submitted to the Lords of H.M. Privy Council as provided in the Charter of the Association.

REGULATIONS

Nomination of President of the Association by Council

1. Suggestions for the Presidency of the Association shall be considered by the Council at the meeting in February, and the names selected shall be issued with the summonses to the Council meeting in March, when the nomination shall be made from the names on the list.

General Committee

2. The President shall take the Chair at meetings of the General Committee at which he is present. In his absence the General Committee shall elect a Chairman.

The Council

3. It shall be competent for the Council to appoint a Chairman thereof to serve for a term not exceeding five years.

4. The President or Chairman for the time being of the Parliamentary and Scientific Committee, if a Member of the Association, shall be invited to become a Member of the Council.

Assistant to the General Treasurer

5. The General Treasurer may depute the Secretary or other officer to carry on under his direction the routine work of the duties of his office. Such officer shall be charged with the issue of membership tickets and such other work as may be delegated to him.

Meeting Rooms

6. The Reception Room and Section Rooms and the approaches thereto shall not be used without sanction for any notices, exhibitions, or purposes other than those of the Association.

The Sections

7. It shall be competent for any Sectional Committee to form a Department for the purpose of dealing separately with any group of communications addressed to the Section.

8. Recorders and Secretaries shall not hold office for more than five years (excluding the year of an Annual Meeting overseas) except at the discretion of the Council in special circumstances.

9. Any report or paper read in any one Section may be read also in any other Section.

Research Committees

10. Research Committees shall be composed of Members of the Association, provided that it shall be competent for the Council to appoint, or for a Research Committee to co-opt, as an assessor or consultative member, any person, not being a Member of the Association, whose assistance may be regarded as of special importance to the research undertaken.

11. The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended ; provided that a Research Committee may apply for leave to retain an unexpended balance when or before its report is presented, due reason being given for such application.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

12. If any payment of travelling expenses be contemplated out of a grant to a Research Committee, such intention shall be reported to the Council, and payment shall be confined to fares.

13. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Committees shall furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and shall state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Corresponding Societies

14. Application made by any Society to be placed on the list of Corresponding Societies may be entertained, provided such application is addressed to the Secretary of the Association on or before June 1 preceding the Annual Meeting at which it is intended that it should be effective.

15. Each Corresponding Society shall forward every year on or before June 1, if requested to do so by the Secretary of the Association, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee.

16. The Sectional Committees shall be desired to transmit to the Secretary, for reference to a Conference of Delegates or to any appropriate Corresponding Societies, copies of any recommendations to be made to the Council bearing upon matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

17. It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

18. The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Finance

Travelling Expenses, etc.

19. The General Treasurer shall be authorised, subject to approval, and within limitations defined, by the Council, to defray travelling and other expenses as follows :—

(i) Fares and postages incurred by the President and General Officers in connection with the Annual Meeting, the meetings of the Council, and other meetings involved by the discharge of their official duties.

(ii) Fares incurred by Members of the Council in attending meetings thereof.

(iii) Fares and subsistence expenses incurred by members of the Staff in connection with attendance at the Annual Meeting and otherwise in the discharge of their duties.

(iv) Fares incurred by Recorders and Secretaries of Sections in connection with attendance at the Annual Meetings and meetings of the Sectional Committees.

(v) Postages and essential clerical expenses incurred by the Recorders (or their Sectional Secretaries on their behalf) in the discharging of their duties, provided that no claim exceeding £10 under this heading by any Recorder in any one year shall be allowed without the express sanction of the Council.

It shall be competent for the Council, if they think desirable, to authorise payments in respect of travelling expenses to Members appointed by them to represent the Association at meetings of other bodies, for which formal invitation has been received.

Publication

20. In the event of the separate publication of addresses or other communications by the Association, it shall be competent for the Council to determine from time to time on what terms, whether alternatively or in addition to reports of the Annual

Meeting, such separate publications may be issued to Members or Associates entitled to receive such reports.

21. Presidents shall be entitled to receive one hundred copies of their addresses without charge, and additional copies at the cost of reproduction. One hundred copies of reports of Research Committees printed in advance of the Annual Meeting shall be provided for use thereat ; additional copies at the discretion of the General Officers. Authors of communications ordered to be printed *in extenso* shall receive twenty-five copies of their communications without charge, and additional copies at the cost of reproduction.

Membership, etc.

22. It shall be competent for the General Treasurer, or the Secretary of the Association duly authorised by him, to issue complimentary membership tickets for any one Annual Meeting to :—

(i) Honorary Members attending the Meeting, and distinguished colleagues in science from British territories overseas and from foreign countries, invited by the Council to attend the Meeting as guests, on the nomination of the Sectional Committees or otherwise.

(ii) The Local Secretaries, Local Treasurers, and Local Sectional Secretaries for the Meeting, and any other persons resident in the locality of the Meeting whose services in connection with the local organisation thereof shall, in the opinion of the Local Secretaries after consultation with the Secretary, entitle them to honorary membership for the Meeting.

23. The General Treasurer shall bring to the notice of the Council, for consideration and action if desirable, any other proposal for the issue of complimentary tickets, save as provided in Regulation 24 below.

24. The Council may before each Annual Meeting (other than meetings overseas), with the assent of the Local Executive Committee, invite Universities and University Colleges in Great Britain to nominate each one or more students in science, not above the standing of B.Sc., as ' British Association Exhibitioners.'

Such Exhibitioners shall receive complimentary students' tickets for the Annual Meeting and their travelling expenses (fares) incurred in attending the Meeting shall be met or assisted out of the funds of the Association in accordance with a scale determined by the Council, and the Council shall consult with the Local Executive Committee as to the defrayment of their subsistence expenses during the Meeting. The Council shall also have power to enter into arrangements with university and other authorities respecting the attendance of other selected students whose expenses shall not fall upon the funds of the Association.

25. It shall be competent for the Sectional Committees to invite or accept communications at any Annual Meeting from persons not already Members or Associates of the Association, and the attention of such persons (if not entitled to complimentary tickets) shall be called to the terms of membership and associateship ; but if any such person shall be unable to attend the Meeting except on the day on which he is to deliver his communication to a particular Section, the Secretary shall have power to issue to him a card of admission to that Section for that day.

26. It shall be competent for the Council to consider and adopt any proposal by a Local Executive Committee for a special admission fee to an Annual Meeting for subscribers to any fund raised to defray local expenses of the Meeting.

27. It shall be competent for the Council to fix a charge for admission to any part of an Annual Meeting, or to any Sectional or Divisional Conference, for persons not being Members or Associates of the Association.

28. It shall be competent for the Council, on the occasion of a Meeting overseas, to require from Members proposing to attend such meeting an expression of their intention to participate in the scientific transactions of the meeting.

Amendments to Regulations

29. Any alteration in, or addition to, any of the Regulations, or any new Regulations, shall be considered by the Council, and, if they so decide, recommended to the General Committee for approval and confirmation ; provided that the Council may bring into operation in the interval between Annual Meetings any amendment consistent with the Statutes, and shall report such amendment to the General Committee at the ensuing Annual Meeting.

REPORT OF THE COUNCIL TO THE GENERAL COMMITTEE FOR THE YEAR 1944–45

(DECEMBER 13, 1945)

OBITUARY

THE Council have to deplore the loss by death of the following office-bearers and supporters :—

Sir Joseph Arkwright, F.R.S.
Dr. F. W. Aston, F.R.S.
Prof. F. G. Baily
W. Barlow, F.R.S.
Sir Buckston Browne, F.R.C.S.
His Grace the Lord Archbishop of Canterbury (Dr. W. Temple)
Prof. Sir Arthur Eddington, O.M., F.R.S.
Sir Ambrose Fleming, F.R.S.
Sir Martin Forster, F.R.S.
Sir Ralph H. Fowler, F.R.S.
Sir John Fox, C.B., F.R.S.
Major E. O. Henrici
Dr. A. R. Hinks, C.B.E., F.R.S.
Dr. S. W. Kemp, F.R.S.
Prof. W. Makower
Sir Peter Chalmers Mitchell, F.R.S.
Dr. C. T. Moody
Sir Percy Nunn
A. W. Oke
Rt. Hon. the Earl of Onslow, P.C., G.B.E.
Major C. E. S. Phillips, O.B.E.
Dr. D. Randall-MacIver, F.B.A.
Prof. J. Holland Rose
Miss E. R. Saunders
Sir Napier Shaw, F.R.S.
T. Sheppard
Sir Charles J. H. Thomas, K.C.B., K.C.M.G.
Dr. J. F. Tocher
Principal A. H. Trow
Sir Duncan Wilson, C.V.O., C.B.E.
Prof. F. Wilson
Prof. J. T. Wilson, F.R.S.
Sir Arthur Smith Woodward, F.R.S.

On the death of Sir Buckston Browne, the Council adopted the following resolution : 'That the Council of the British Association record their deep regret at the death of an outstanding benefactor of the Association, from whom the Association received the gift of Down House, the home of Charles Darwin. By his generous act Sir Buckston Browne laid upon the Association the honourable custody of a lasting memorial to one of the greatest names in the advancement of science.'

The President, Sir Richard Gregory, represented the Association at the funeral of Lord Dawson of Penn. Prof. D. Brunt, F.R.S., General Secretary, represented the Association at the funeral of Sir Napier Shaw.

REPRESENTATION

The Association was represented at the Victory Congress of L'Association Française pour l'Avancement des Sciences in Paris, October 1945, by the President and Lady Gregory, Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S., Sir Edward Appleton, F.R.S., Lt.-Col. W. Campbell Smith, and Prof. E. N. da C. Andrade, F.R.S., the delegates being the guests of the French Association. The President conveyed an address of congratulation from the Council, who received a report of the Congress from him, and forwarded their thanks to the French Association for its generous reception of the delegation. It is hoped to publish an account of the Congress by Prof. J. Verne, Secretary of the French Association.

The Association was invited by the Ministry of Education to forward comments on the draft constitution of the United Nations Educational, Scientific and Cultural Organisation, and empowered the General Officers to formulate these in consultation with the Royal Society. Dr. O. J. R. Howarth, Secretary, subsequently attended a meeting of representatives of interested bodies convened by the Minister of Education, at which the draft constitution was discussed in preparation for the United Nations Conference of delegates summoned to establish the organisation.

Prof. D. M. S. Watson, F.R.S., represented the Association at the celebration of the 220th anniversary of the foundation of the Academy of Sciences, U.S.S.R., in Russia.

The President, Sir Richard Gregory, Bt., F.R.S., represented the Association on a deputation to H.M. Government from societies occupying premises in Burlington House, when the need for more adequate accommodation for these and other scientific societies was urged.

At the P.E.N. commemoration of the tercentenary of the publication of Milton's *Areopagitica*, the Association was represented by Dr. M. Davidson, Prof. H. Dingle, and Prof. E. T. Whittaker, F.R.S.

At the Manchester Literary and Philosophical Society's commemoration of the centenary of the death of John Dalton, F.R.S., the Association was represented by Sir Arthur P. M. Fleming, C.B.E.

The Association was represented by Prof. H. Wasteneys at the installation of the President of the University of Toronto, Dr. S. E. Smith.

Prof. J. N. Mukherjee was appointed to represent the Association at the meeting of the Indian Science Congress Association in Bangalore, January, 1946.

COMMUNICATIONS WITH OTHER INSTITUTIONS

The American Association for the Advancement of Science thanked the General Committee and the Council for their expressions of condolence on the death of President Franklin D. Roosevelt, which was announced on the day of meetings of both bodies, April 13, 1945.

Messages have been exchanged with the Greek Mathematical Society of Athens and the Anti-fascist Society of Latvian Scientists.

The congratulations of the Council were conveyed to the New York Botanical Garden and to the British Optical Association on the occasion of their jubilees.

The South African Association for the Advancement of Science has reported the award of the South Africa medal and grant for 1943–44 to Prof. C. van Riet Lowe, and those for 1944–45 to Dr. V. C. H. Barnard.

The Council have had the pleasure of admitting as a Corresponding Society the National Veterinary Medical Association of Great Britain and Ireland.

Division for the Social and International Relations of Science

The Division held a Conference on the Place of Science in Industry on January 12–13, 1945, of which a report has been published in *The Advancement of Science*, and another on Scientific Research and Industrial Planning, on December 7–8, 1945, of which a report will be published in due course.

The Divisional Committee consists of the President and General Officers, Prof. F. C. Bartlett, F.R.S., Prof. J. D. Bernal, F.R.S., Mr. Ritchie Calder, C.B.E., Mr. J. G. Crowther, Dr. C. H. Desch, F.R.S., Mr. W. C. Devereux, Prof. P. Sargant Florence, Prof. C. Daryll Forde, Prof. A. V. Hill, Sec. R.S., Dr. Julian Huxley, F.R.S., Mr. A. Gray Jones, Dr. D. P. Riley, Sir John Russell, F.R.S., Prof. E. J. Salisbury, C.B.E., F.R.S., Dr. R. E. Slade, Dr. D. Williams, Mr. J. S. Wilson. Their thanks are due to all who have helped in the framing and carrying out of the programmes of the conferences.

Publication

The continuation of the annual grant of £400 towards the cost of printing, made by the Royal Society from the Rockefeller fund at its disposal, has enabled the publication of *The Advancement of Science* to be maintained, and to include some of the articles on applications of science which, as indicated in the previous report of the Council, it is intended to issue as separate pamphlets as soon as conditions permit.

The Council, on the General Committee's instruction, examined the possibility of producing a yearbook of science under the auspices of the Association; but in present conditions they are unable to recommend this.

Future Annual Meetings

After full inquiry, the Council have found it impossible that an Annual Meeting of the Association on the customary lines should be held in 1946. None of the cities in which meetings would have been held but for the war, nor others where the question has been considered, is in a position to invite the Association for that year, though invitations for subsequent years may be expected. Indeed, one from Brighton for the year 1948 has already been accepted, and at the instance of the authorities there the date has been fixed, subject to the General Committee's approval, for September 14–21.

In these circumstances the Council have decided that the Annual Meeting in 1946 shall take place on one day only, in London. The Council and the General Committee will hold their statutory sessions thereat, and a general meeting will be held, at which Sir Richard Gregory, Bt., F.R.S., will deliver the Presidential Address. The General Officers are making inquiry as to a suitable hall, and the date, which is expected to be in the second half of July, will be settled in consultation with the Royal Society and Government authorities, since it is intended to invite to the meeting, and also to entertain, Dominions and foreign scientific delegates who will be in England for the Empire Scientific Conference and the International Council of Scientific Unions at that time.

The meeting for a single day will not afford occasion for the usual sectional transactions; but the Council do not exclude the possibility of sectional or divisional conferences being held on other occasions in 1946, and sectional officers and committees will be consulted in this connection.

A proposal from the Société Jersiaise for a visit to Jersey was answered with the suggestion that the Brighton meeting in 1948 might afford convenient opportunity for a representative party to pay such a visit.

Statutes [1]

Under the power delegated to them by the General Committee, the Council accepted two recommendations made by the Clerk to the Privy Council in considering the revision of the Statutes submitted for the approval of the Lords of the Council. These recommendations were: (1) that the original statement of the objects of the Association be retained, since if the statement were revised as submitted, it would be necessary to supplicate for a supplementary Charter; (2) that the copyright clause in the Statutes (XI, 2) should be more precise in definition. The following form of words was agreed: 'The copyright of all addresses lectures and papers whatsoever published by the Association, and of Research Committees appointed by the General Committee or the Council, shall be vested in the Association. It shall be competent for the Council to assign the copyright of any address, lecture, paper or report.'

Officers and Council

The Council have nominated Sir Richard Gregory, Bt., F.R.S., to continue in office as President of the Association during the year 1946. At the Annual Meeting, 1946, they will submit to the General Committee a nomination to the Presidency of the Association for the year 1947.

The Council have nominated Sir Harold Hartley, K.C.V.O., F.R.S., as General Treasurer, and Prof. F. T. Brooks, F.R.S., Prof. D. Brunt, F.R.S., and Prof. Allan Ferguson as General Secretaries, until the Annual Meeting, 1946. They will then submit nominations for the period from that meeting until the Annual Meeting, 1947. The pre-war procedure in respect of nominations of President and General Officers will then be restored.

During the period covered by this report, the Council, under Regulation 3, have appointed Dr. C. Tierney as Chairman of the Council. They have also appointed Mr. M. G. Bennett as Assistant General Treasurer.

The Council have appointed Mr. D. N. Lowe to be Secretary of the Association in succession to Dr. O. J. R. Howarth, who in normal circum-

[1] Since this report was adopted, the revised Statutes have received the approval of H.M. Privy Council.

stances would have retired in 1942. They have asked Dr. Howarth to remain in office until the next Annual Meeting of the Association, and to act as Joint Secretary with Mr. Lowe if he should in the meantime be released from his wartime service in the Ministry of Production.

At the Annual Meeting, 1946, the Council will submit to the General Committee a list of nominations to ordinary membership of the Council for the ensuing year, in accordance with normal procedure. Meanwhile the Council are about to co-opt certain new members with a view to further representation of the various departments of science, since during the war the personnel of the Council has become depleted.

Finance

The General Treasurer's Account for the year 1943–44 has been audited and is presented to the General Committee. Grants have been made to Research Committees in accordance with the schedule appended to the Account.

The following grants have been approved for the year 1945–46 :

	£	
Seismological Investigations Committee	100	(Caird Fund)
Mathematical Tables Committee—renewal of grant already authorised but not yet drawn : for the printing of Airy Tables (£130) and Legendre Tables (£80)	210	,, ,,
Mathematical Tables Committee, for secretarial expenses, etc.	25	,, ,,
'Zoological Record' Committee	50	,, ,,
Plymouth Laboratory Committee	50	,, ,,
Algae and Protozoa Committee (final grant)	25	,, ,,
Carried forward	£460	
Brought forward	£460	
Freshwater Biological Station, Windermere, Committee	75	(Musgrave Fund)
Kent's Cavern Committee	5	(Hobson Fund)
	£540	

The Mathematical Tables Committee was given authority to negotiate with the Cambridge University Press for the printing of its second volume of Bessel functions tables.

Down House

The Darwin Memorial Rooms at Down House were reopened to the public on October 22, 1945. It is a matter of intense satisfaction that in spite of its hazardous position during the war, the house suffered no major damage by enemy action, and the memorial collection none at all. Important additions to the collection were received during the war ; this has necessitated much rearrangement, and a new catalogue is in preparation. The Council have approved recommendations by the House Committee concerning the future staffing of the house, the continuation in residence there of Dr. Howarth after his retirement from the secretaryship of the Associaton, and the need for an appeal, at a suitable time, for a substantial increase in the endowment fund. This will be necessitated not only by the need for overtaking six years' arrears of repairs and the inevitable increase of running costs in the future, but also by the desirability of maintaining the property and its equipment in a condition befitting its high object, and of assisting towards its appropriate use as a centre of scientific research.

The Council welcome the continued maintenance of the experimental bed of *Lythrum salicaria* by Prof. R. A. Fisher, F.R.S., and Dr. K. Mather, referred to in previous reports, and they hope, with the Committee and in accordance with the wish of the late Sir Buckston Browne, the donor, to see an expansion of such work at Down.

The amount of precipitation registered by the standard rain-gauge in 1944 was 29·25 in.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

GENERAL TREASURER'S STATEMENT AND ACCOUNT, 1944–45

THE accounts for 1944–45 differ little from those of previous war years. They show a credit balance of £177, thanks to the grant of £400 by the Royal Society from the Rockefeller Foundation Fund and a payment of £486 from the Yarrow Fund.

Now that the war is ended it is an appropriate time to report how the Association has weathered the storm so far as its finances are concerned and what financial problems are involved in the resumption of its full peace-time activities. The accounts for each year except one have shown a balance of income over expenditure on the general account, the total balances for the years between 1939 and 1945 being £1,483. This has only been made possible by annual subventions amounting in all to £2,630 from the Yarrow Fund and by grants amounting to £1,000 by the Royal Society from the Rockefeller Foundation Fund towards the cost of publications. But we must not forget the careful economy which has been exercised by all the officials of the Association, to whom we owe a debt of gratitude for the efficiency with which they have carried on the affairs of the Association during the war years.

Only £1,334 now remains in the Yarrow Fund, and according to the Deed of Gift it should have been used completely by September, 1946. Apart from this, our capital funds have remained intact during the war, strengthened by the transfer to the Contingency Fund of £1,483, the total excess of income over expenditure since 1939, and by legacies of £500 and £1,000, both for general purposes, under the wills of Dr. C. D. Sherborn and Lady Lockyer. The value of the stocks held in the General Fund has increased by £8,855 since 1939, including fresh investments of £2,983. The income from investments, however, has fallen owing to a reduction in the average rates of interest from 4 per cent. in 1939 to 3½ per cent. in 1945.

The General Committee have by a recent decision limited the period over which financial assistance may be given to special researches or projects. This is in conformity with the original conception of the Association of initiating, rather than indefinitely subsidising, new researches. This decision is likely to reduce the total sum granted for research in future, unless new projects are initiated. Next year's account will show a legacy of £2,090 in 3½ per cent. Conversion Stock, under the will of the late Mr. Arthur Haydock, for the special purpose of original investigation on geology and botany.

During the war our average annual expenditure has been only £3,000 in place of an average of roughly £5,000 for the five pre-war years. As soon as we can hold an Annual Meeting again there will be a large increase in membership, but it is doubtful whether this alone will solve all our financial problems. The Yarrow Fund will soon be used up, and with the increased cost of everything our normal budget must be greater in future. In addition, it is desirable that the Association should be able to meet from its own funds some of the expenses which in the past have fallen on the local funds. Also, improved office accommodation more worthy of the prestige of the Association is badly needed, and substantial additional income will be required for the maintenance of Down House, the home of Darwin, which the Association holds in trust as a national memorial. Increased financial support is therefore essential if the Association is to continue to promote 'general interest in science and its applications' and to fulfil a purpose for which no other Institution provides.

H. HARTLEY,
General Treasurer.

Balance Sheet, 31st March, 1945

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES

	£ s. d.	£ s. d.
General Purposes :—		
Sundry Creditors	141 9 2	
Amounts received in advance for publications	210 1 7	
Membership subscriptions in advance	57 9 0	
		408 19 9
Hon. Sir Charles Parsons' gift (£10,000) and legacy		12,000 0 0
Sir Alfred Ewing's legacy		500 0 0
Dr. C. D. Sherborn's legacy		500 0 0
Lady Mary Lockyer's legacy (1944)		1,000 0 0
British Science Guild: Capital Fund		3,431 9 1
Accumulated Fund		15,542 6 5
Yarrow Fund		
As per last Account	1,820 12 0	
Less Transferred to Income and Expenditure Account under terms of gift	486 5 8	
		1,334 6 4
Life and Corporation Membership Compositions		
As per last Account	4,333 19 2	
Add Received during year: Life Compositions	315 0 0	
	4,648 19 2	
Less Transferred to Income and Expenditure Account	70 10 0	
		4,578 9 2
Grants Equalisation Fund		2,000 0 0
Contingency Fund		
As per last Account	1,689 7 10	
Add Excess of Income over Expenditure for the year, on General Account	177 0 9½	
		1,866 8 7½
Overseas Delegations Fund		781 3 11
Secretary's Pension Fund		
As per last Account	2,100 19 5	
Add Income for the year	75 0 0	
		2,175 19 5
[44,939 2 9]		46,119 2 8½
Special Purposes :—		
Caird Fund		
Capital as per last Account	9,928 17 9	
Revenue balance as per last Account	325 17 1	
Add Excess of Income over Expenditure for the year	112 11 10	
	438 8 11	
[10,254 14 10]		10,367 6 8
Mathematical Tables Fund		
As per last Account	169 3 6	
Add Receipts from sales (Grant not yet drawn, £25)	22 3 9	
[169 3 6]		191 7 3
Cunningham Bequest Fund		
As per last Account	1,378 10 10	
Add Income for the year	62 6 0	
[1,378 10 10]		1,440 16 10
Toronto University Presentation Fund		
Capital	178 11 4	
Revenue balance as per last Account	16 12 6	
Add Income for the year	6 2 6	
	22 15 0	
[195 3 10]		201 6 4
Bernard Hobson Fund		
Capital	1,000 0 0	
Revenue balance as per last Account	161 12 4	
Add Income for the year	34 12 2	
	196 4 6	
[1,161 12 4]		1,196 4 6
[58,098 8 1] Carried forward		59,516 4 8½

ASSETS

	£ s. d.	£ s. d.
General Purposes :—		
Investments as scheduled with Income and Expenditure Account, No. 1	45,523 11 1	
Sundry debtors and payments in advance	73 12 11	
Cash at bank	506 11 9	
Cash in hand	15 6 11½	
[44,939 2 9]		46,119 2 8½
Special Purposes :—		
Caird Fund Account		
Investments (see Income and Expenditure Account, No. 2)	9,928 17 9	
Cash at bank	438 8 11	
[10,254 14 10]		10,367 6 8
Mathematical Tables Fund Account		
Cash at bank	170 18 6	
Debtor	20 8 9	
[169 3 6]		191 7 3
Cunningham Bequest Fund Account		
Investments (see Income and Expenditure Account, No. 3)	1,240 12 4	
Cash at bank	195 4 6	
Debtor	5 0 0	
[1,378 10 10]		1,440 16 10
Toronto University Presentation Fund Account		
Investment (see Income and Expenditure Account, No. 4)	178 11 4	
Cash at bank	22 15 0	
[195 3 10]		201 6 4
Bernard Hobson Fund Account		
Investments (see Income and Expenditure Account, No. 5)	1,000 0 0	
Cash at bank	196 4 6	
[1,161 12 4]		1,196 4 6
[58,098 8 1] Carried forward		59,516 4 8½

Balance Sheet, 31st March, 1945 (*continued*)

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES (*continued*)

		£ s. d.	£ s. d.
[*58,098 8 1*]	Brought forward		59,516 4 3½
	Leicester and Leicestershire Fund, 1933		
	Capital	1,000 0 0	
	Revenue balance as per last Account . . 31 16 8		
	Less Excess of Expenditure over Income for the year . . . 25 15 10		
		6 0 10	
[*1,031 16 8*]			1,006 0 10
	Property Rehabilitation Fund		
	Balance as per last Account . .	347 15 8	
	Less Excess of Expenditure over Income for the year . . .	17 4 9	
		330 10 11	
	Creditor	1 4 7	
	Cash balance overdrawn . .	68 4 6	
[*400 0 0*]			400 0 0
	Radford Mather Lecture Fund		
	Capital	250 0 0	
	Revenue balance as per last Account . . 20 1 11		
	Add Income for the year 9 6 8		
		29 8 7	
[*270 1 11*]			279 8 7
	Mrs. E. M. Musgrave's Legacy (1944)	300 0 0	
	Less Expenditure for the year .	75 0 0	
[Nil]			225 0 0
	Down House		
	Endowment Fund . . .	21,204 17 8	
	Library Fund	10 10 0	
	Suspense Account		
	Balance as per last Account . . . 363 14 6½		
	Add Excess of Income over Expenditure for the year . . . 109 14 0		
		473 8 6½	
	Creditors	21 15 5	
[*21,579 4 6½*]			21,710 11 7½
[*81,379 11 2½*]			£83,137 5 4

ASSETS (*continued*)

		£ s. d.	£ s. d.
[*58,098 8 1*]	Brought forward		59,516 4 3½
	Leicester and Leicestershire Fund, 1933, *Account*		
	Investments (see Income and Expenditure Account, No. 6) .	1,000 0 0	
	Cash at bank	6 0 10	
[*1,031 16 8*]			1,006 0 10
	Property Rehabilitation Fund Account		
	Investment (see Income and Expenditure Account, No. 7) .	400 0 0	
[*400 0 0*]			400 0 0
	Radford Mather Lecture Fund Account		
	Investment (see Income and Expenditure Account, No. 8) .	250 0 0	
	Cash at bank	29 8 7	
[*270 1 11*]			279 8 7
	Mrs. E. M. Musgrave's Legacy Account (see Income and Expenditure Account, No. 9)		
	Cash at bank		225 0 0
[Nil]			
	Down House Account		
	Endowment Fund investments (see Income and Expenditure Account, No. 10). . . .	21,204 17 8	
	Sundry debtors and payments in advance	63 5 5	
	Cash at bank	416 16 11	
	Cash in hand	25 11 7½	
[*21,579 4 6½*]			21,710 11 7½
[*81,379 11 2½*]			£83,137 5 4

We have examined the foregoing Account with the Books and Vouchers and certify the same to be correct. We have also verified the Balance at the Bankers and the Investments, and have inspected the Deeds of Down House.

Approved:
EZER GRIFFITHS
ROBERT S. WHIPPLE } *Auditors.*
12th July, 1945.

W. B. KEEN & CO., *Chartered Accountants*,
224 Regent Street, London, W. 1.
12th July, 1945.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31st MARCH, 1945

No. 1. General Income and Expenditure

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investments at cost :		
£25,762 16*s.* 4*d.* Consolidated 2½ per cent. Stock		19,296 7 6
£1,000 0*s.* 0*d.* 3 per cent. Savings Bonds 'A,' 1960/70		1,000 0 0
£5,268 19*s.* 0*d.* 3 per cent. Savings Bonds 'B,' 1955/65		5,268 19 0
£150 0*s.* 0*d.* 3 per cent. Savings Bonds, 1965/75		150 0 0
£879 14*s.* 9*d.* Great Indian Peninsula Railway 'B' Annuity £43		827 15 0
£52 12*s.* 7*d.* 3½ per cent. War Stock (Post Office issue)		54 5 2
£7,849 16*s.* 8*d.* 3½ per cent. War Loan Stock		7,905 15 10
£6,368 15*s.* 7*d.* 3½ per cent. Conversion Stock		5,304 8 11
£4,184 18*s.* 2*d.* 3 per cent. Local Loans		3,073 12 2
£1,000 0*s.* 0*d.* 4 per cent. Funding Loan		1,170 0 0
£100 0*s.* 0*d.* 5 per cent. Great Western Railway Consolidated Pref. Stock		125 0 0
£345 16*s.* 8*d.* 3 per cent. London County Consolidated Stock 1956/61		347 7 6
£981 10*s.* 0*d.* 4 per cent. Commonwealth of Australia Stock 1955/70		1,000 0 0
[*Value of stocks at 31/3/44, £48,686 17s. 1d.*]	(Value at 31/3/45, £51,213 7*s.* 4*d.*)	
[*44,373 11 1*]		£45,523 11 1
Cash at bank and in hand		£521 18 8½

EXPENDITURE

		£ s. d.
To Heat, Lighting and Power		39 5 3
„ Stationery		53 0 0
„ Rent		1 0 0
„ Postages		83 14 8½
„ Travelling expenses		15 0 10
„ Audit		31 10 0
„ Subscription to Parliamentary and Scientific Committee		10 10 0
„ Hire of meeting rooms		10 16 0
„ Reporting of Division meetings		20 14 2
„ General expenses		109 17 5½
„ Salaries and wages		2,120 15 9
„ Pension contributions		80 2 0
„ Printing, etc.		466 13 2
„ Translation from Russian (Publications Account)		34 13 0
„ Payments to authors for contributions to "The Advancement of Science" to be reprinted as pamphlets		105 0 0
„ Air raid precautions at Burlington House		32 3 3
„ War damage insurance (contents)		2 0 0
„ Post-war University Education Committee luncheon		10 14 6
„ Luncheon to Indian scientists visiting London		14 9 6
[*3,197 0 0*]		3,251 19 7
„ Balance, being excess of Income over Expenditure for the year, transferred to Contingency Fund [*100 8 3*]		177 0 9½
[*3,297 8 3*]		£3,429 0 4½

INCOME

		£ s. d.
By Annual membership subscriptions		357 9 0
„ Life compositions : amount transferred on expiry of membership		70 10 0
„ Sale of publications	£391 12 10½	
Less amount transferred to Mathematical Tables Fund	22 3 9	
		369 9 1½
„ Royal Society (Rockefeller grant)		400 0 0
„ Advertisements in B.A. publications		66 12 0
„ Income Tax recovered		79 15 6
„ Interest on investments		1,474 4 6
„ Interest on current account		7 13 7
„ Rental of accounting machine by Ministry of Supply		50 0 0
„ Air raid precautions : amount transferred from Property Rehabilitation Fund		32 3 3
„ War damage claims paid		10 15 9
„ Contributions to Post-war University Education Committee luncheon		10 19 6
„ Contributions to luncheon to Indian scientists		13 2 6
„ Yarrow Fund : amount of capital transferred *		486 5 8
[*3,297 8 3*]		£3,429 0 4½

* YARROW FUND

The amount shown in the Balance Sheet is the balance of a gift of £10,000 received from Sir Alfred Yarrow in September, 1926, to be used 'as the authorities controlling the Association may think best in the interests of science,' without restriction other than that the capital as well as income must be expended within approximately twenty years.

No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£2,627 0*s.* 10*d.* 3 per cent. Savings Bonds 'A,' 1960/70	2,627 0 10
	£2,100 0*s.* 0*d.* London Midland and Scottish Railway 4 per cent. Preference Stock	2,190 4 3
	£2,000 0*s.* 0*d.* Southern Railway 5 per cent. Preference Stock	2,594 17 3
	£2,716 16*s.* 6*d.* 3½ per cent. War Loan Inscribed Stock	2,516 15 5
[*Value of stocks at 31/3/44, £9,362 8s. 0d.*]	(Value at 31/3/45, £9,466 12*s.* 8*d.*)	
[*9,928 17 9*]		£9,928 17 9
	Cash at bank	438 8 11

EXPENDITURE

	£ s. d.
To Grants (see Schedule) [*430 0 0*]	265 0 0
„ Balance, being excess of Income over Expenditure for the year [– – –]	112 11 10
[*430 0 0*]	377 11 10
Grants authorised, not yet drawn :—	
Mathematical Tables	210 0 0
Zoological Record	50 0 0
Bird Behaviour	20 0 0
[*280 0 0*]	£280 0 0

INCOME

	£ s. d.
By Dividends and Interest [*343 18 3*]	265 17 10
„ Income Tax recovered	111 14 0
„ Balance, being excess of Expenditure over Income [*86 1 9*]	– – –
[*430 0 0*]	£377 11 10

No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers ; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£1,187 6*s.* 10*d.* Consolidated 2½ per cent. Stock	653 0 9
	£300 0*s.* 0*d.* Port of London 3½ per cent. Stock 1949/99	216 0 0
	£737 2*s.* 10*d.* Local Loans 3 per cent. Stock	371 11 7
[*Value of stocks at 31/3/44, £1,936 18s. 3d.*]	(Value at 31/3/45, £1,994 6*s.* 1*d.*	
[*1,240 12 4*]		£1,240 12 4
	Cash at bank	£195 4 6

EXPENDITURE

	£ s. d.
To Balance, being Income for the year	62 6 0
[*62 6 0*]	£62 6 0

INCOME

	£ s. d.
By Dividends and Interest	57 1 0
„ Income Tax recovered	5 5 0
[*62 6 0*]	£62 6 0

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£175 0*s.* 0*d.* 3½ per cent. War Stock	178 11 4
[*Value at 31/3/44, £182 8s. 9d.*)	(Value at 31/3/45, £184 3*s.* 9*d.*)	
	Cash at bank	22 15 0

EXPENDITURE

	£ s. d.
To Balance, being Income for the year	6 2 6
[*6 2 6*]	£6 2 6

INCOME

	£ s. d.
By Interest	6 2 6
[*6 2 6*]	£6 2 6

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933; the income to be applied to the promotion of geological research; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£50 0s. 0d. 4 per cent. Victory Bonds . .	55 10 5
	£601 9s. 0d. 3 per cent. Local Loans . .	508 6 6
	£416 0s. 11d. 3½ per cent. War Loan Inscribed Stock	436 3 1
	Value at 31/3/44, £1,055 1s. 10d.] (Value at 31/3/45, £1,070 15s. 6d.)	
[1,000 0 0]		£1,000 0 0
	Cash at bank	196 4 6

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Balance, being Income for the year . .	34 12 2	By Interest	34 12 2
		„ Income Tax recovered	— — —
[39 2 2]	£34 12 2	*[39 2 2]*	£34 12 2
Grant authorised, not yet drawn :— Kent's Cavern . .	5 0 0		
[5 0 0]	5 0 0		

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£487 2s. 11d. 3½ per cent. Conversion Stock .	500 0 0
	£490 5s. 11d. 3½ per cent. War Stock . .	500 0 0
	[*Value of stocks at 31/3/44, £1,017 15s. 6d.*] (Value at 31/3/45, £1,031 3s. 11d.)	
[1,000 0 0]		£1,000 0 0
	Cash at bank	6 0 10

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Grants (see Schedule)	60 0 0	By Interest . . . . . *[34 4 2]*	34 4 2
		„ Balance, being excess of Expenditure over Income for the year . . . . . *[20 15 10]*	25 15 10
[55 0 0]	£60 0 0	*[55 0 0]*	£60 0 0

No. 7. Property Rehabilitation Fund (incorporating balance of the Herbert Spencer Bequest Fund)

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investment at cost :	
	£398 4s. 3d. 3 per cent. London County Consolidated Stock, 1956/61	400 0 0
	[*Value of stocks at 31/3/44, £402 3s. 10d.*] (Value at 31/3/45, £404 3s. 8d.)	
[400 0 0]		£400 0 0
	Cash balance overdrawn	£68 4 6

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Down House Income and Expenditure Account : Cost of Air Raid Precautions at Down House *[14 14 9]*	— — —	By Interest	11 18 10
		„ Income Tax recovered . . . . . *[14 18 7]*	2 19 8
„ General Income and Expenditure Account : Cost of Air Raid Precautions at Burlington House . . . . . *[42 3 5]*	32 3 3	„ Balance, being excess of Expenditure over Income for the year . . . . . *[41 19 7]*	17 4 9
[56 18 2]	£32 3 3	*[56 18 2]*	£32 3 3

No. 8. Radford Mather Lecture Fund

A gift of £250 received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting the expense of triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investment at cost :		
£248 17*s.* 8*d.* 3 per cent. London County Consolidated Stock, 1956/61		250 0 0
[*Value of stock at 31/3/44,* £251 7*s.* 5*d.*]	(Value at 31/3/45, £252 12*s.* 3*d.*)	
[250 0 0]		£250 0 0
Cash at bank		£29 8 7

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Balance, being Income for the year	9 6 8	By Interest	7 9 4
		„ Income Tax recovered	1 17 4
[9 6 8]	£9 6 8	[9 6 8]	£9 6 8

No. 9. Mrs. E. M. Musgrave's Legacy

A legacy of £300, received in 1944, "for the development of biological research, with special reference to the investigation of the fresh water fauna of English lakes and to the grant of small sums to young research workers specially in need of financial assistance."

Cash at bank £225

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Grant (see Schedule)	75 0 0	By Balance, being Expenditure for the year	75 0 0
	£75 0 0		£75 0 0

No. 10. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (later Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment of £20,000 to the Association as a gift to be held as a memorial to Darwin in custody for the nation.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investments at cost :		
DOWN HOUSE ENDOWMENT FUND		
£2,500 Commonwealth of Australia 5 per cent. Stock, 1945/75		2,468 19 0
£3,000 Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock		2,139 17 3
£2,500 New South Wales 5 per cent. Stock, 1945/65		2,467 7 9
£2,500 Western Australia 5 per cent. Stock, 1945/75		2,472 1 6
£3,340 Great Western Railway 5 per cent. Consolidated Guaranteed Stock		3,436 7 5
£2,500 Birkenhead Railway 4 per cent. Consolidated Stock		2,013 9 9
£7,944 2*s.* 4*d.* 2½ per cent. Consolidated Stock, Inscribed		6,206 15 0
[*Value of stocks, 31/3/44,* £23,813 9*s.* 0*d.*]	(Value at 31/3/45, £24,399 2*s.* 4*d.*)	
[21,204 17 8]		£21,204 17 8
Cash at bank and in hand		£442 8 6½

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Wages of Staff	599 11 5	By Rents receivable	194 0 7
„ Rates, Insurance, etc.	90 12 4	„ Income Tax recovered	373 10 0
„ Electricity	43 2 0	„ Dividends and interest	572 2 0
„ Fuel	97 3 8	„ Sale of postcards and photographs	1 0
„ Drainage Plant	12 15 5		
„ Water	17 16 6		
„ Repairs and Renewals	18 0 4		
„ Land and Garden: materials and maintenance	81 18 2		
„ Donations to village institutions	15 5 0		
„ Household requisites, etc.	9 9 1		
„ Transport and carriage	1 11 10		
„ Printing, postage, telephone, stationery	6 15 3		
„ War Damage Insurance (Contents)	7 10 0		
„ War Damage Contribution	14 12 3		
„ War Damage repairs carried out	13 16 4		
[922 13 4½]	1,029 19 7		
„ Balance, being excess of Income over Expenditure for the year, transferred to Suspense Account	109 14 0		
[241 1 11½]			
[1,163 15 4]	£1,139 13 7	[1,163 15 4]	£1,139 13 7

Schedule of Grants Paid to Research Committees, etc.

during the financial year to March 31, 1945

NOTE.—The year indicated in brackets after the title of each committee is that of its original appointment, and the sum, if any, is that previously expended out of grants by the Association.

	£ s. d.	£ s. d.
1. Paid out of the General Fund		
Post-war University Education Committee (1942: £228 18*s.* 9*d.*)		12 12 2*
2. Paid out of the Caird Fund		
Seismology (1895: £5,320 14*s.* 8*d.*)	100 0 0	
Plymouth Laboratory (1886: £1,698 10*s.* 8*d.*)	50 0 0	
Zoological Record (1923: £985)	50 0 0	
Algæ and Protozoa (1939: £125)	25 0 0	
Bird Behaviour (1938: £120)	20 0 0	
International Commission on Zoological Nomenclature (£20)	20 0 0	
		265 0 0
3. Paid out of Cunningham Bequest (1929)		
Mathematical Tables†		– – –
4. Paid out of the Leicester and Leicestershire Fund, 1933		
J. L. Crammer (£60)	30 0 0	
Dr. J. D. Smyth	30 0 0	
		60 0 0
5. Paid out of the Bernard Hobson Fund (1933)		– – –
6. Paid out of the Mathematical Tables Fund (1934)		
Mathematical Tables†		– – –
7. Paid out of Mrs. E. M. Musgrave's Legacy (1944)		
Freshwater Biological Station (1930: £1,012 15*s.* 11*d.*)		75 0 0
		£412 12 2

* This is an estimated figure, not shown separately in the Income and Expenditure Account.

† Mathematical Tables

Total grants paid to March 31, 1945:—

	£ s. d.	£ s. d.
From Cunningham Bequest	2,835 18 11	
„ Caird Fund	1,202 8 2	
„ Mathematical Tables Fund	187 16 0	
„ General Fund	415 17 6	
„ Royal Society Grant (1933)	50 0 0	
	4,782 0 7	
Amount recovered by sale of tables	520 10 7	
Amount recovered by hire of accounting machine by Ministry of Supply	245 1 8	
	765 12 3	
	£4,016 8 4	

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THE BRITISH ASSOCIATION

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